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A COMPUTER PROGRAM FOR THE PREDICTION OF SOLID PROPELLANT ROCKET MOTOR PERFORMANCE. VOLUME II

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Ultrasystems, Incorporated

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A COMPUTER PROGRAM FOR THE PREDICTION OF SOLID PROPELLANT ROCKET MOTOR PERFORMANCE, VOL. III

FINAL REPORT

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JULY 1975

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FOREWORD

This report was submitted by Ultrasystems, Inc., Environmental and Applied Sciences Division, 2400 Michelson Drive, Irvine, California 92664, under Contract No. F04611-73-C-0038, Job Order No. 305909LZ with the Air Force Rocket Propulsion Laboratory, Edwards, CA 93523.

This report consists of three volumes. Volume I describes a computer program for the prediction of Solid Propellant Rocket Motor Performance. The computer program described herein will be referred to as the SPP program, and describes the engineering analysis which was used in developing this computer program and the results obtained to date.

Volume II of this report is a programming document of the computer program which was developed under this contract. It includes a subroutine-by-subroutine description of all of the elements of the SPP program.

Volume III of this report is a Program User's Manual which describes the input necessary to execute the SPP computer program and the information required to interpret the output. A sample case is also included.

This report has been reviewed by the Information Office/DOZ and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This report is unclassified and suitable for public release.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A flexible, modular, fully automated, solid rocket motor performance prediction program has been developed. The program, which has been given the acronym SPP is based on six pre-existing computer codes. These codes have been integrated and modified, as required. To supplement the theory, where necessary, and to increase the flexibility of the program, a number of existing and newly developed semi-empirical correlations were incorporated into the program. The program has a general three-dimensional grain design capability, coupled to a one-dimensional ballistics analysis. The deviations from ideal performance are

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computed as a series of independent efficiencies. The program currently treats the following losses: two-dimensional/two-phase (coupled), nozzle erosion, kinetics, boundary layer, combustion efficiency, submergence. The program predicts average delivered performance, as well as mass flow, pressure, thrust, impulse, and specific impulse as functions of time and trajectory.

In order to assess the validity of the SPP program, calculated results were compared to firing data for four different types of motors. While conclusive statements regarding the accuracy and range of validity of the SPP program cannot be made until additional verification efforts are conducted, the results of these four test cases were encouraging. These calculations also served to demonstrate the desirability of eliminating some of the present limitations of the program.

PREFACE

This is Volume III of a three-part manual which describes a computer program for the prediction of Solid Propellant Rocket Motor Performance. The computer program described herein will be referred to as the SPP program.

Volume I of this report describes the engineering analysis which was used in developing this computer program.

Volume II of this report is a programming document of the computer program which was developed under this contract. It includes a subroutine-by-subroutine description of all of the elements of the SPP program.

Volume III of this report is a Program User's Manual which describes the input necessary to execute the SPP computer program and the information required to interpret the output. A sample case is also included.

TABLE OF CONTENTS

1. METHOD OF APPROACH

The goal of the present effort was to develop a computerized analysis technique that could predict delivered specific impulse to within ±2%, and delivered thrust coefficient and total impulse to within ±5%. The method of approach used in the development of the Solid Rocket Performance Program (SPP) stressed modularity and flexibility. The program was designed so that the various elements which comprise the total performance prediction methodology could be utilized as an integrated set, individually, or in any user determined combination. In most cases both analytical and empirical methods have been incorporated into the program to account for the phenomena which causes motor performance to deviate from a specified "ideal." The user, depending on his needs, can select either method. The option is phenomena oriented, so some effects may be treated empirically (simple, short computation time) while others can be evaluated analytically (more calculation time, greater accuracy and generality).

The program has been structured in a modular fashion to allow future improvements and modifications to be easily incorporated. The program modules (with the exception of the master control module) are pre-existing computer programs which have been adapted for the present purpose. The following pre-existing programs were used as the basis for the SPP program:

- One Dimensional Equilibrium Program (ODE)[1]
- One Dimensional Kinetics Program (ODK)[2]
- Two Dimensional Two Phase Program (TD2P)[3]
- Turbulent Boundary Layer Program (TBL)[4]
- Three Dimensional Grain Design Program (64101)[5]
- Motor Ballistics Program (637)[6]

These programs have been combined with a control module which permits them to be run together automatically. The extensive use of internal communication between modules has just about eliminated the need for redundant inputs by the user.

The next two subsections will define the "losses" which have been considered and the manner in which delivered performance is calculated. The balance of the section briefly describes the various modules, what they do, how they do it, and their inter-relationships.

1.1 Terminology and Definition of Losses

The basic method of approach used in the development of the SPP computer program is to calculate the maximum or ideal 'theoretical' performance of a rocket motor and to subtract from that maximum performance the individual losses or deviations from the "theoretical" performance which are known to occur in a real rocket motor. This method of approach is neither new to the field of rocket performance prediction or engineering analysis in general. It is, however, founded on our understanding of the basic physical processes involved in a real rocket motor and the interrelation of these processes with each other.

The basic assumption involved in this type of approach is that certain "losses" can be treated as essentially independent from the other losses which occur in the rocket motor. As noted in Section 1.2, all of the losses should not be treated independently. There are some interactions strong enough to warrant consideration. With these exceptions in mind, the concept of treating the losses independently appears to be valid, considering the success of this approach and others of a similar nature.

The term "loss" as used here is really a misnomer, since it is used to describe a known physical mechanism or phenomena which causes the performance of a "real" solid rocket motor to be less than the so-called "theoretical" performance. In the same sense the terminology "theoretical," or "ideal," is also a misnomer, because the whole methodology incorporated herein is based on our theoretical understanding of the processes which are present in real rocket motors. However, this terminology has gained wide spread acceptance in the engineering community and will be used in this report.

In order to further define the terminology used here the following definitions will be used:

- **Performance** - unless otherwise specified, performance will be in terms of specific impulse, I_{sp}, delivered to a vacuum.
- **Theoretical I_{sp}** - the maximum possible I_{sp} which can be delivered at the initial area ratio by a propellant at a given chamber pressure and total enthalpy. Referred to as $I_{sp_{th}}$.
- **Loss** - the decrement from the theoretical I_{sp} which can be attributed to a physical phenomena not included in the calculation of $I_{sp_{th}}$.

- **Two phase flow loss** - the decrement in performance due to finite velocity and temperature differences between the gas and condensed phase.
- **Two dimensional or divergence loss** - the decrement in performance which is due to the momentum of the rocket exhaust not being totally aligned with the axis of the motor.
- **Finite Rate Kinetics loss** - the decrement in performance which is due to incomplete transfer of latent heat to sensible heat caused by the finite time required for gas phase chemical reactions to occur.
- **Boundary Layer Loss** - the decrement in performance due to viscous forces adjacent to the nozzle wall and heat transfer to the nozzle wall.
- **Combustion Efficiency** - as used here, the term combustion efficiency will refer only to the degradation of I_{sp} due to a departure of chamber total temperature from the theoretically calculated total temperature.
- **Submergence Loss** - the decrement in performance due to propellant grain extending pass the nozzle inlet.
- **Erosion Loss** - the decrement in performance due to the erosion of the nozzle throat. This loss encompasses both area ratio effects (considered only in the TD2P module) and throat roughness effects (not considered in the present analysis)
- **Delivered Performance** - the calculated performance of the rocket motor which includes all of the losses considered herein.

With our terminology now defined, we can now describe the rational and methods used by the SPP computer program to calculate the delivered performance of a solid rocket motor.

1.1.1 Calculation of Delivered Performance

Within the framework already discussed (i.e., separation of individual losses), there are three basic methods which can be used to calculate delivered I_{sp}. The first method is to calculate discrete decrements in performance, ΔI_{sp}, and to subtract these losses from the theoretical specific impulse, $I_{sp_{th}}$. That is

$$I_{sp_D} = I_{sp_{th}} - \Sigma \Delta I_{sp_{loss}} . \qquad (1\text{-}1)$$

The second method is to calculate a series of efficiencies, η's, to be applied multiplicatively, i.e.

$$I_{sp_D} = I_{sp_{th}} \prod \eta_{loss} \, . \tag{1-2}$$

Both of the above methods are the same through first order, thus, if the losses are small they yield the same result.

The third method was selected by the JANNAF Committee on Performance Standardization for liquid rocket engines and is a combination of the first two methods. That is, all of the losses except the boundary layer loss are treated as efficiences while the boundary layer loss is treated as a decrement. Hence,

$$I_{sp_D} = I_{sp_{th}} \prod \eta_{loss} - \Delta I_{sp_{BL}} \tag{1-3}$$

This latter method of approach was selected for incorporation in the SPP code for two reasons. The first reason being that there was no compelling reason to deviate from what has been established as a "standardized" method in the industry, and secondly, that any other combination of the above methods yields substantially the same end result.

The main problem associated with the separation technique is, of course, the selection of a base or reference value of performance to compare against the model which incorporates the loss. Ideally, this reference calculation should be made by the same computer code which is selected to make the loss calculation since this would minimize deviations due to numerical techniques, truncation and roundoff errors. However, as is generally the case, such an approach is not practical. For example, both the equations for the two [illegible] flow and chemical kinetics losses become "stiff" in the equilibrium limit [illegible] result in unacceptably long and difficult calculational procedures. Even if sophisticated numerical techniques are used to calculate the "near" equilibrium case, extrapolation to the full equilibrium solution introduces errors which negate any advantage gained by using the same computer code. Hence, the following criteria was adopted in calculating the reference performance for each of the losses (except the boundary layer loss which is calculated directly).

> The reference method should be the most exact method of calculation available. The conceptual differences between the reference and loss models should include only those mechanisms which cause the loss.

TABLE 1-1 INTERACTION OF PHYSICAL PHENOMENA WITH PERFORMANCE LOSS CALCULATIONS

PERFORMANCE LOSSES / PHENOMENA	Divergence Loss	Boundary Layer Loss	Kinetic Losses	Two-Phase Flow Losses	Combustion Inefficiency Loss
Non One-Dimensional Flow	X	1	2	2	3
Viscous And Heat Transfer	3	X	3	2	3
Finite Rate Chemistry	3	2	X	3	3
Multiphase Flow	1	2	2	X	3
Incomplete Combustion	3	2	2	3	X

Legend:

1. Primary Importance (could be > 0.2% effect on I_{sp})
2. Secondary Importance (probably < 0.2% effect on I_{sp})
3. Generally Not Important

Table 1-1 (from Ref. 9), shows the interaction of the physical phenomena considered here with each of the performance losses. The table should be read down and then to the left. For example, the main interaction between the divergence loss and the various physical phenomena is that associated with multi-phased flow, while the boundary layer loss is chiefly affected by the nature of the specified boundary layer edge conditions, (i.e., from a one or two-dimensional flow field calculation). Table 1-2 is a condensation of Table 1-1, and indicates only those cross coupling effects that were deemed strong enough to warrant consideration.

Table 1-2 Cross Coupling of Performance Losses

Loss Mechanism	Cross Coupling
Finite Rate Chemistry (Kinetics)	none
Divergence Loss	Two Phase Flow
Two Phase Flow	none
Boundary Layer Loss	Non One-Dimensional Flow
Combustion Efficiency Loss	none

Table 1-2 shows that while the kinetics, two phase flow and combustion efficiency losses can be treated independently, the divergence and boundary layer losses are coupled to non-one-dimensional and two phase flow phenomena, respectively. Hence, it was decided that the best course of action to take in the SPP code was to couple the two phase flow and divergence losses together and to use the results of that calculation to obtain the edge conditions for the boundary layer calculation.

With the above in mind, the following sub-sections describe the basic modules and assumptions used in the SPP code.

1.2 Master Control Module (MC)

The master control module (MC) controls the execution of the SPP computer code. The MC module selects, via user input, which of the five basic calculation modules (ØDE, BAL, ØDK, TD2P, and TBL) are to be executed, and whether calculated, input, or empirical, losses are to be selected for the calculation of delivered specific impulse, thrust, and total impulse.

This module handles or specifies all of the linkage communications between modules. The MC module selects which parameters (either calculated or input) are transmitted from one module to another and tries to determine the best overall delivered performance consistant with the input to the SPP computer program.

Figure 1-1 shows the basic input and output of the MC module, while Table 1-3 shows the variables used to calculate delivered thrust, I_{sp}, and total impulse and indicates the module in which each is calculated.

Table 1-3 Variables Used for Performance Prediction by the MC Module

Module	Variable
ØDE/One Dimensional Equilibrium	$I_{sp_{th}}$, $I_{sp_{REQ}}$, ϵ
BAL/Grain Design and Ballistics	I_c, $\dot{m}$, r^*, L^*, η_{c*} as functions of t
ØDK/One Dimensional Kinetics loss	$I_{sp_{KIN}}$, ϵ
TD2P/Two Dimensional Two Phase flow loss	$I_{sp_{TD2P}}$, η'_{TD2P} as functions of ϵ_j; and C_D
TBL/Turbulent Boundary Layer loss	$\Delta I_{sp_{TBL}}$

The vacuum delivered specific impulse is calculated as in equation 1-3 and is written in full here.

$$I_{sp_D} = I_{sp_{th}} \eta_{KIN} \cdot \eta_{TD2P} \cdot \eta_{CE} \cdot \eta_{SUB} - \Delta I_{sp_{TBL}} \qquad (1-4)$$

The theoretical specific impulse, $I_{sp_{th}}$, is based on the initial nozzle exit area ratio. If a motor experiences throat erosion during the course of a firing the nozzle exit area ratio, and hence, the specific impulse, varies with time. This gives rise to an additional loss mechanism; one which was only mentioned but not discussed in Section 1.1. The performance decrement associated with this phenomena is usually called the erosion loss. While this loss can be estimated based on one-dimensional calculations, it was felt that a two-dimensional estimate of this effect would be superior. Thus, for eroding nozzles, η_{TD2P} in equation (1-4) is modified as follows:

$$\eta_{TD2P} = \overrightarrow{\eta}_{TD2P} \frac{I_{sp_{TD2P}}(\bar{\epsilon})}{I_{sp_{TD2P}}(\epsilon_i)} \qquad (1-5)$$

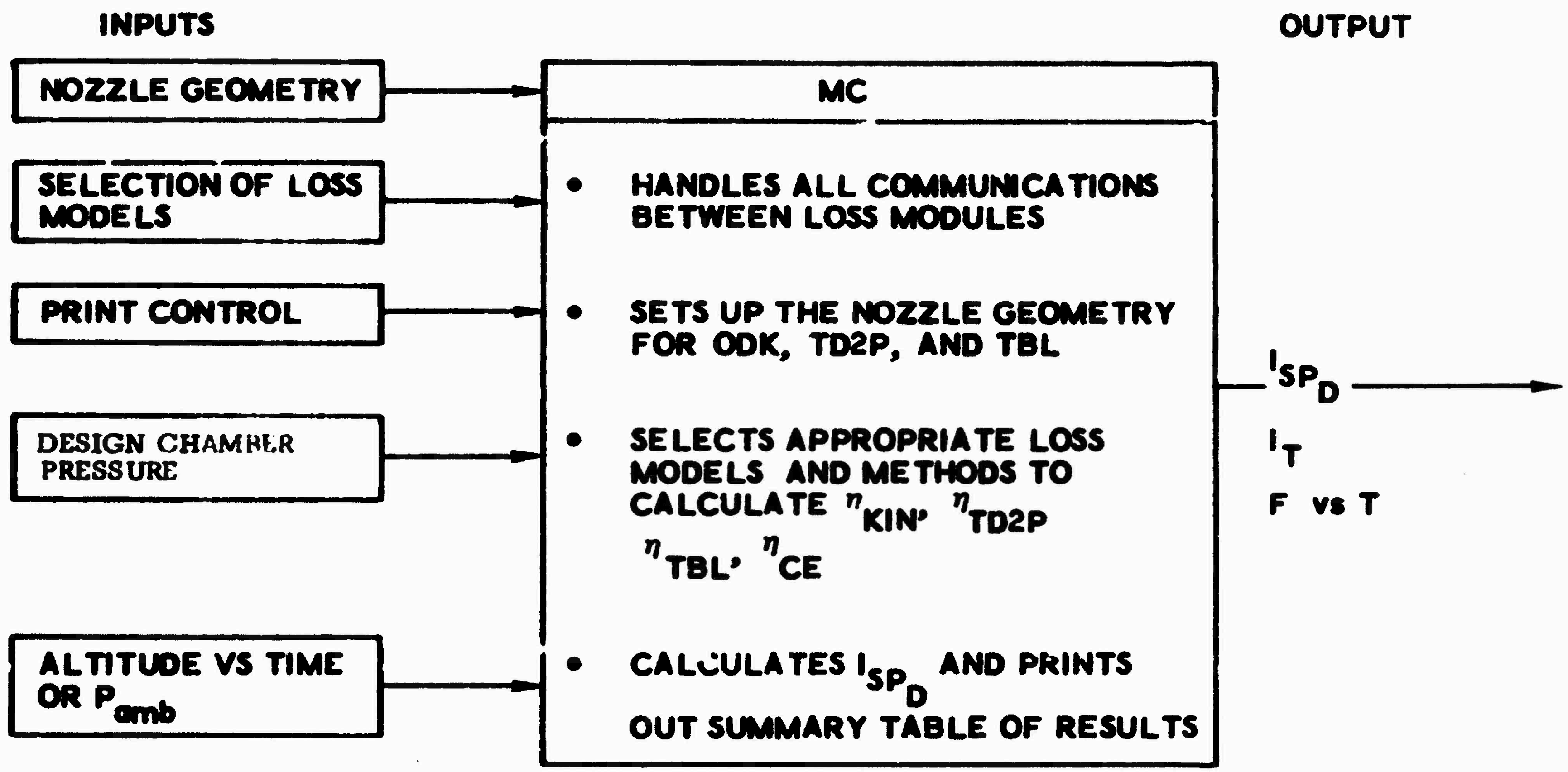


FIGURE 1-1 MASTER CONTROL MODULE (MC)

where

$$\overline{\eta}'_{TD2P} = \frac{\int_{t_o}^{t_f} \eta' \left(\epsilon(t)\right) dt}{t_f - t_o}$$

When defined in this way η_{TD2P} includes the "erosion" loss in addition to the coupled two-phase and divergence losses. The erosion loss, as defined herein, is equal to the ratio of the 2-D, 2-phase I_{sp} at the time averaged expansion ratio, $I_{sp_{TD2P}}(\overline{\epsilon})$, to the specific impulse evaluated at the initial expansion ratio, $I_{sp_{TD2P}}(\epsilon_i)$. (Future modifications to the program should break the erosion loss out as a separate efficiency.)

The combustion efficiency, η_{CE}, is defined as follows:

$$\eta_{CE} = C_D \cdot \overline{\eta}_{c^*} \tag{1-6}$$

or

$\eta_{CE} = 1.0$, if the previous relation yields a value greater than unity.

This definition prevents the mass flow effect related to the nozzle discharge coefficient, C_D, from being counted twice since it is an integral part of the 2D-2 phase loss. In the empirical performance prediction procedure η_{CE} is taken to be equal to η_{c^*}. The empirical determination of c* efficiency is discussed in Volume I of this report.

The loss due to finite rate chemical kinetics is treated as an efficiency factor, η_{KIN}. The kinetic efficiency is calculated as the ratio of an I_{sp} calculated by the ODK module, to an I_{sp} calculated by a special option in the ODE module. This special ODE option, referred to as the "Restricted Equilibrium" option causes the ODE program to compute an I_{sp} based on the more restrictive physical assumptions employed in the ODK calculation. This procedure is necessary if certain losses are not to be counted twice. The aforementioned assumptions are described in Section 1.5.

The submergence efficiency, η_{SUB}, is based on an empirical correlation one is a function of the throat radius, mass fraction of condensed phase, length of submergence to length of the internal motor, and chamber pressure. This correlation is discussed in more detail in Volume I of this report.

The decrement in performance due to the formation of a turbulent boundary layer in the motor nozzle is transmitted directly to the MC module and is reported as a function of area ratio. The decrement in I_{sp} is taken to be the value corresponding to the last (i.e. the maximum) area ratio input by the user. This decrement is assumed to be independent of erosion induced area ratio changes (it is more a function of the wetted length of the nozzle) and throat roughness.

The equations used to calculate the "theoretical" performance losses, and the formulas used in the "empirical", or simplified, performance calculations are presented in Volume I and Volume II.

1.3 Theoretical I_{sp} Module (ØDE)

The theoretical I_{sp} module (ODE) is an outgrowth of the NASA Lewis chemical equilibrium computer program described in NASA SP-273 (Reference 1) and in the JANNAF standard TDK computer program manual (Reference 2).

This module calculates the theoretical, or maximum, I_{sp} which can be delivered by a propellant at a given area ratio. The ODE module uses a free energy minimization technique along with the following assumptions to calculate the vacuum I_{sp}.

One dimensional flow

Thermal and velocity equilibrium of the condensed phase with the gas phase flow

This version of the ODE program has also been modified to calculate the transport properties needed by the ballistics (BAL) module, two phase flow loss (TD2P) module, and the boundary layer loss (TBL) module.

In addition, the program has been modified to calculate the reference condition for the loss in performance due to finite rate chemical kinetics. This option is referred to as the "restricted equilibrium" option and is discussed in more detail in section 1.5.

Figure 1-2 illustrates the major functions of the ODE module as well as the inputs and outputs of the module.

1.4 Grain Design and Ballistics Module

When utilized as part of the overall performance prediction methodology

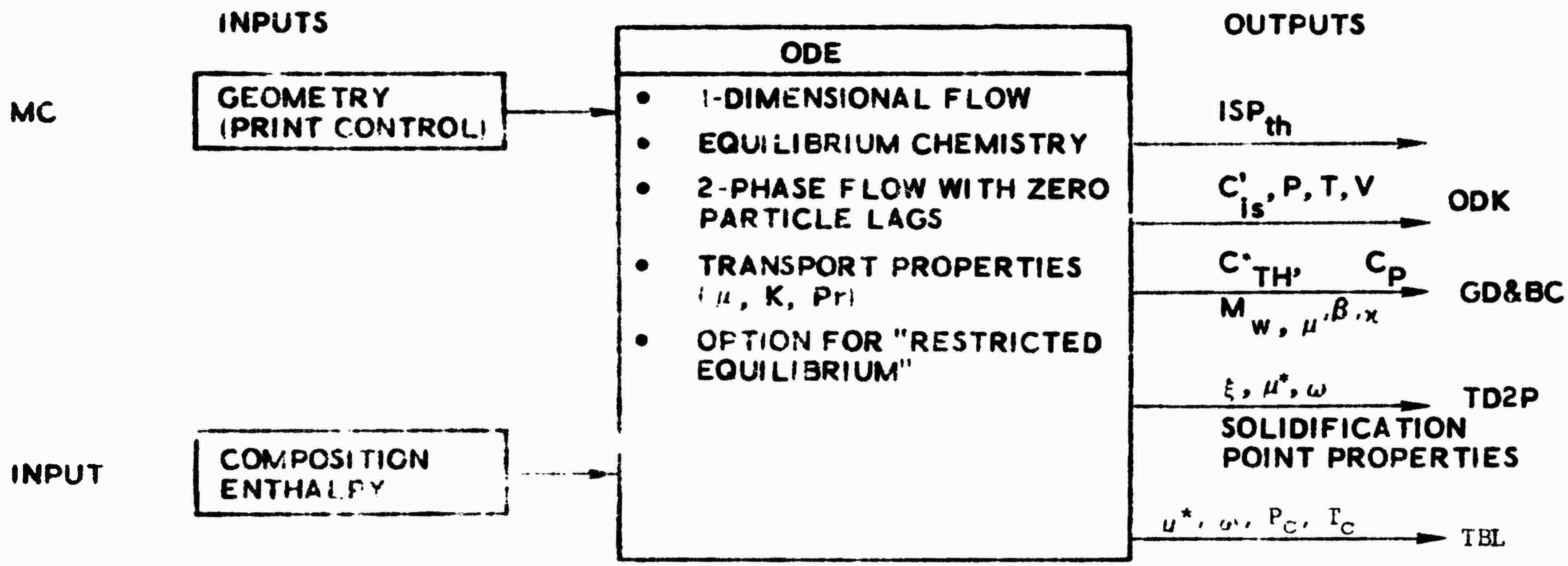


FIGURE 1-2 THEORETICAL ISP MODULE (ØDE)

the purpose of the Grain Design and Ballistics (GD&BC) module is to provide values of pressure, mass flow rate, throat radius, L*, and C* efficiency, as functions of time. Time averaged values of these quantities are also computed and used in the other modules. Figure 1-3 illustrates how the GD&BC module functions in this mode of operation. Various thermodynamic and transport properties are internally transmitted to the GD&BC module from the ODE module. Likewise, the nozzle geometry and ambient pressure history are obtained from the Master Control module. The final thrust versus time output of the programs in this integrated mode of operation are based on the GD&BC calculated chamber pressure and mass flow rate; the delivered I_{sp} is calculated from the combined results of the other modules.

The GD&BC module can also be employed in a stand-alone mode. In this case, all of the parameters which would otherwise be supplied by the ODE and MC modules must be input directly into the Ballistics module. The thrust versus time curve in this mode of operation is based on the calculated mass flow rate, an empirical C* efficiency, and an input value of nozzle (C_f) efficiency.

The essential features of the GD&BC module are:

The Hercules Inc. 64101 grain geometry analysis program, omitting non-essential elements for considerable size reduction, and modified to be compatible with the Lockheed Propulsion Company interior ballistics analysis program.

An improved version of the Lockheed Propulsion Company 637 interior ballistics analysis program.

A correlation of C* efficiency.

A correlation of nozzle throat erosion

1.4.1 Grain Geometry Program

The Grain Design Program examines a grain in three dimensions and solves for the surface versus burn distance relationship. The grains are not limited to families of grains such as star, slotted tube, etc., but will handle these and more complex grains. A detailed users manual for the original Hercules 64101 program exists as Ref. (5). The following extracts are essential portions for present purposes.

1.4.1.1 Method of Approach

The Grain Design Program simulates drafting techniques used in developing the surface area versus burn distance curve of a solid propellant motor, given

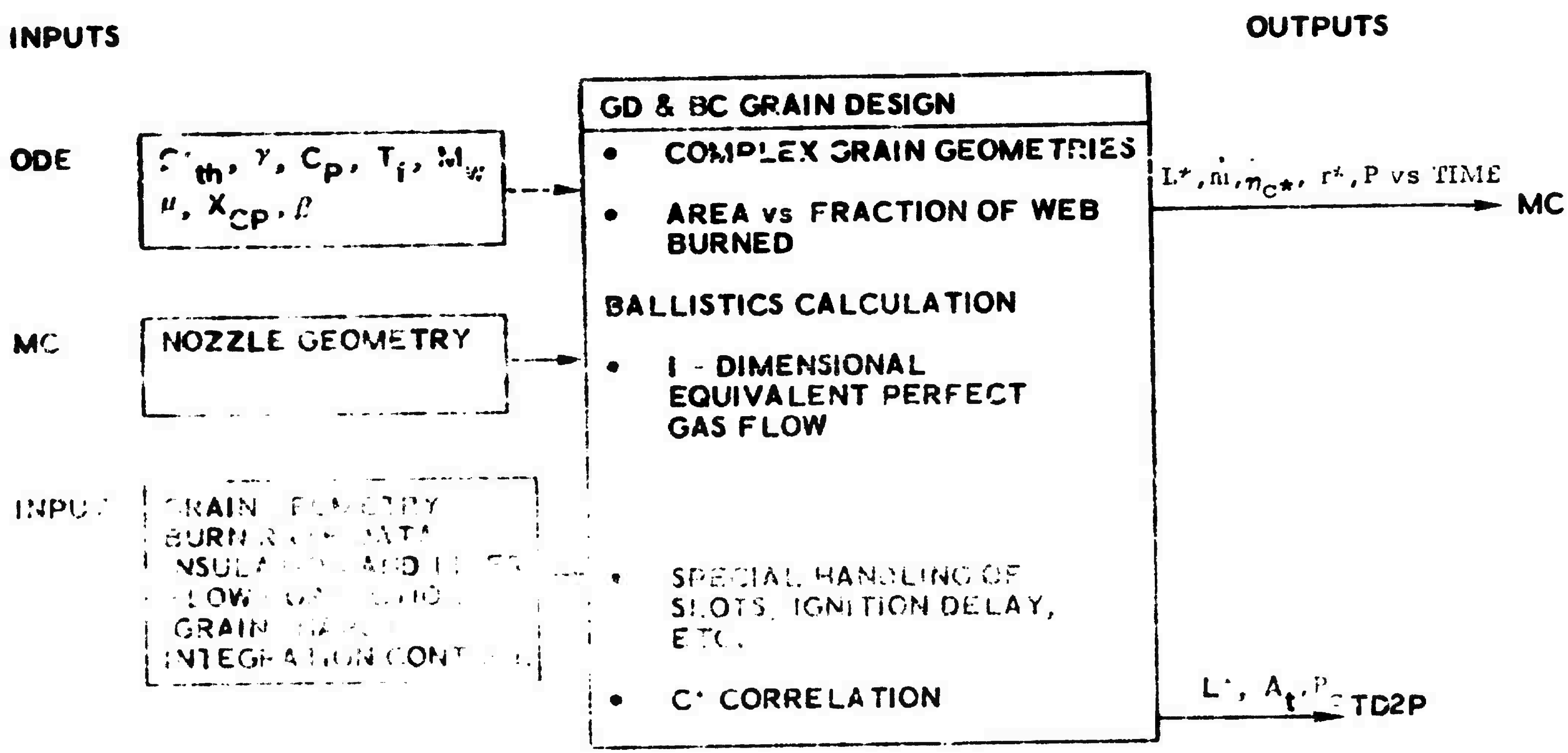


FIGURE 1.3 GRAIN DESIGN AND BALLISTICS CALCULATION MODULE (GD & BC)

an arbitrary number of symmetrical angular sectors. The program uses a right-handed orthogonal coordinate system in X, Y, Z where X is the longitudinal axis passing along the center line of the motor and the Y and Z axes pass from the center of the motor to the outer boundary.

Three basic input figures are used in various combinations to describe the initial propellant geometry. These figures are: frustrum of a right circular cone, right triangular prism, and a sphere. A union of the input figures is performed by computing the intersection of a line Y=C and each of the input figures. The overlapping points are eliminated and those left represent the propellant geometry at the particular X, Y and burn coordinate consistent with the symmetry of the propellant.

Each figure may be input as consisting of void or propellant, where the void is burning outward and the propellant is burning inward. Since the burning is assumed normal to the surface and the surface area is equal to the derivative of the volume of the propellant with respect to the normal, the surface is computed as the derivative of the volume of the propellant with respect to the burn distance. Volume can be computed as the integral of the propellant areas at each X station with respect to X, and propellant area can be expressed as the integral of the lengths across the propellant with respect to Y.

1.4.1.2 General Description of the Solution

The basic mass balance equation

$$\dot{m} = s\, r\, \rho \qquad (1\text{-}7)$$

is the basis for the solution. By eliminating time and density, equation (1-7) becomes

$$s = dv/db \approx \Delta v/\Delta b \qquad (1\text{-}8)$$

and from the mean value theorem s will occur somewhere in the interval Δb. The half-way point was arbitrarily accepted.

m = mass

r = rate of burn

ρ = mass density

s = burning surface area

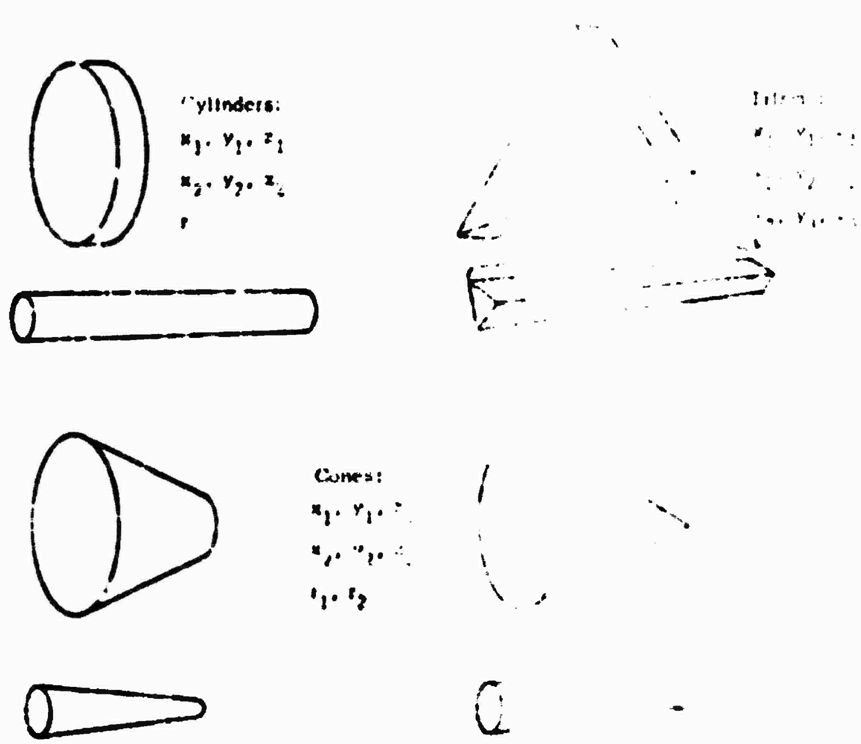
v = volume of propellant

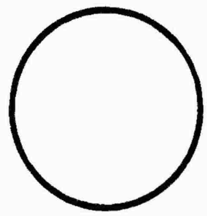
b = burn distance

In the solution for b versus s the program does not make any direct analytic solution for a burning surface, but rather makes calculations for the volume of propellant at each burn distance specified in the input, records the change in volume between two consecutive burn distances, and divides by the difference in the two burn distances. Thus, the user should keep in mind that he is preparing input to simulate the changes in volume which will occur in the motor, not to directly compute burning surface areas.

1.4.1.3 Method of Determining Volumes: Configuration Simulation

The case is assumed full of propellant initially. The voids in the case are simulated by figures - cones, cylinders, prisms, or spheres - which may overlap and/or protrude outside the case, if needed. They should simulate the void as it is initially. The figures may be normal outburning figures, grain-fill inburning figures, or nonburning figures and may have rounded corners and edges, if needed. The order of input can be important. Each figure may be placed in any orientation anywhere in space, inside or outside of the grain. Each of these is described in detail later. Each figure is located in three dimensional space by the following means.





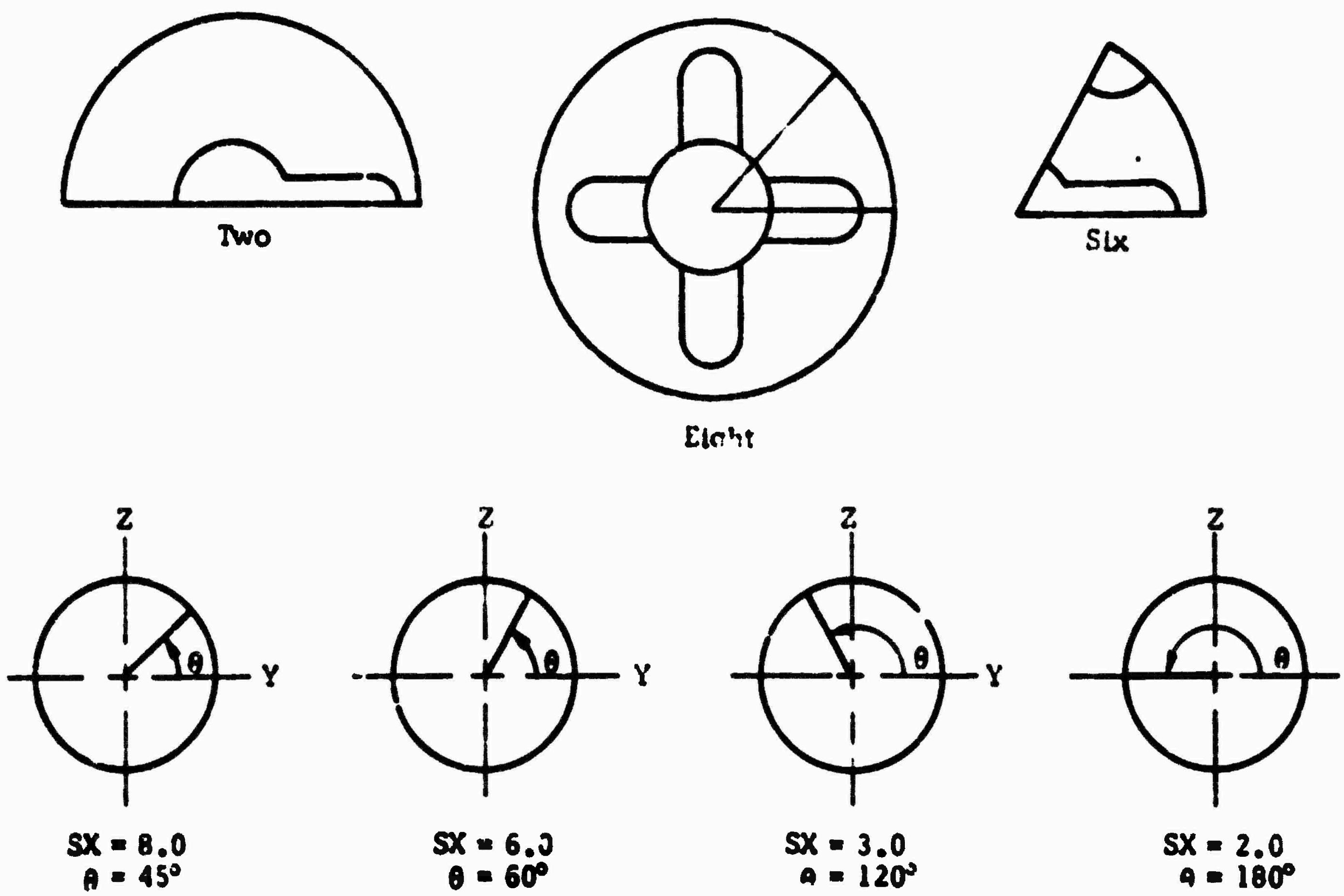
Spheres:

x_1, y_1, z_1

r

Generally, the grain will be symmetric about the axis of the motor. If there are symmetries in the grain they should be reflected in the input in order to save work and computer time. See Figure 1-4. The symmetries are automatically accounted for in the whole motor.

Figure 1-4: Sample symmetries: (End views of motors)



(The X axis is perpendicular to the paper)

1.4.2 Interior Ballistics

The Interior Ballistics Program models the internal ballistics of solid rocket motors, including motor environmental effects on burning rate (erosion, radiation), effects of radial slots between segments on the port flow port flow pressure drop, and delayed burning (ignition) in deep narrow slots. Semi-empirical correlations for combustion inefficiency and nozzle throat erosion also are included. This digital computer program was adapted from an existing model used to analyze nozzleless solid rocket motors[6]. It was selected because it contains features lacking in many published internal ballistics programs. The intent was to predict internal ballistics for motors ranging from small tactical motors, to large boosters, wherein aspects of all the aforementioned features are encountered. The major effort in the present program development involved updating certain model expressions, and rendering the computational procedure compatible with the Grain Design Module and the balance of the SPP Program Modules.

1.5 Finite Rate Chemical Kinetics Loss Module (ØDK)

In most rocket motors there is a loss of performance due to the fact that a finite time is required for chemical reactions to proceed to the maximum amount of sensible heat release. Normally, this loss is caused by the incomplete recombination in the rocket nozzle of the highly energetic species which are formed during combustion in the rocket motor.

The ØDK module only considers the losses which are due to gas phase chemical kinetics. Other losses which include incomplete or partial solidification of condensed phases are ignored in the ODK module since adequate models of these processes have yet to be formulated. The ODK module also assumes that the flow is one dimensional, with the gas and condensed phases in dynamic and thermal equilibrium with each other. No transfer of mass between gas phase species and the condensed phase species are allowed. The liquid phase, however, is allowed to undergo solidification when the gas temperature reaches the melting temperature of the condensed phase.

In order to properly calculate the chemical kinetic performance efficiency, η_{KIN}, a reference equilibrium I_{sp} which is based on the same assumptions as ODK

should be used. In order to provide this reference value; the ØDE module was modified to calculate a "restricted equilibrium" specific impulse $I_{sp_{RE}}$. This modification to the ODE module allows the available gas phase species to remain in chemical equilibrium with themselves while restricting any mass transfer to the condensed phases. Hence, the kinetic performance efficiency, which is defined as

$$\eta_{KIN} = I_{sp_{ODK}} / I_{sp_{RE}}$$

would approach unity as the chemical kinetic reaction rate constants approach infinity.

Another advantage of the use of the restricted equilibrium option for computing kinetic efficiencies is that only thermodynamically important species need be considered in the ODK-3E calculations. Thus, trace species, and reactions involving them, need not be included in this calculation.

Figure 1-5 shows the basic input, output and assumptions used in the ODK module. A comprehensive set of reactions for aluminized propellants is also included in the volume. (See Table 2-13) Appendix A of Volume I indicates how the reactions and species where selected for aluminized propellants.

1.6 Two Dimensional-Two Phase Loss Module (TD2P)

Almost all rocket nozzles of practical interest have a loss in performance due to a nonaxial component of velocity at the nozzle exit plane. This loss is usually referred to as a divergence, or two dimensional flow, loss. If the propellant is metalized, there is an additional loss when the particles cannot maintain a state of dynamic and thermal equilibrium with the gas flow. This loss is referred to as the two phase flow loss.

There are two distinct coupling effects between the two dimensional and two phase flow losses. The first is that if the gas and condensed phase are not in dynamic (velocity) equilibrium with each other then the gas and particle streamlines are not coincident . This can have a noticeable effect on the divergence loss. The second coupling effect is on the mass flux through the nozzle. It is now well known that the mass flow through a nozzle for single phase two dimensional flow is less than the amount of mass flow that can be achieved at a given chamber pressure for an equivalent one dimensional nozzle flow. This effect results in nozzle discharge coefficients being less than unity. However, it is also well

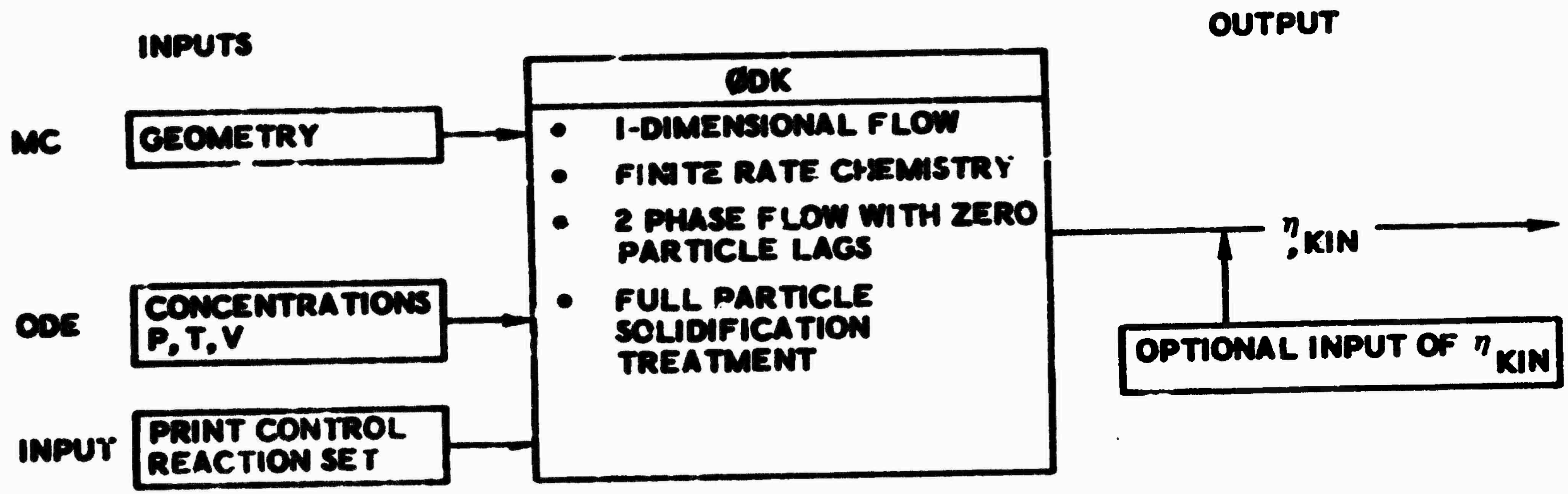


FIGURE 1-5 ANALYTICAL KINETICS LOSS MODULE (ØDK)

known that in nonequilibrium two phase flow more mass flows through a nozzle at a given chamber pressure than would if the particles were in velocity and thermal equilibrium. By itself, this effect would produce C_D values greater than unity. For most metalized solid propellant motors the net result of these two opposing effects is a discharge coefficient greater than unity. If the combustion efficiency were 100% (complete combustion) the C* efficiency of the motor, η_{c^*}, is given by

$$\eta_{c^*} = \frac{1}{C_D} \quad ,$$

Thus, in most cases, η_{c^*} would be less than unity for metalized propellants, and would always be greater than unity for non-metalized propellants*. As a result of the relationship between η_{c^*} and C_D, the C_D effect must be corrected out of the empirically obtained c* efficiency if one is to obtain a value for combustion efficiency which does not count this factor twice.

The TD2P module is a modified version of the computer program developed by Kliegel and Nickerson (Ref. 3). This module, which has been extensively modernized, calculates the losses which are usually the largest encountered in most solid rocket motors. These losses are, the two phase flow loss, erosion loss, and divergence loss.

The basic inputs, characteristics, and outputs of the TD2P module are shown in Figure 1-6. Since this is the most important loss module in the SPP code it is felt that the following comments are in order.

---

*Most solid rocket motors have normalized radii of curvature ≈ 2 and, in the absence of particles C_D tends to be $.99 \leq C_D < 1$, or, in other words, with perfect combustion η_{c^*} would be bounded as follows, $1 < \eta_c^* \lesssim 1.01$. This small effect tends to be masked by measurement and data reduction errors, and many times test engineers are loathe to report values of η_c^* greater than unity due to the mistaken assumption that such values are physically impossible to achieve.

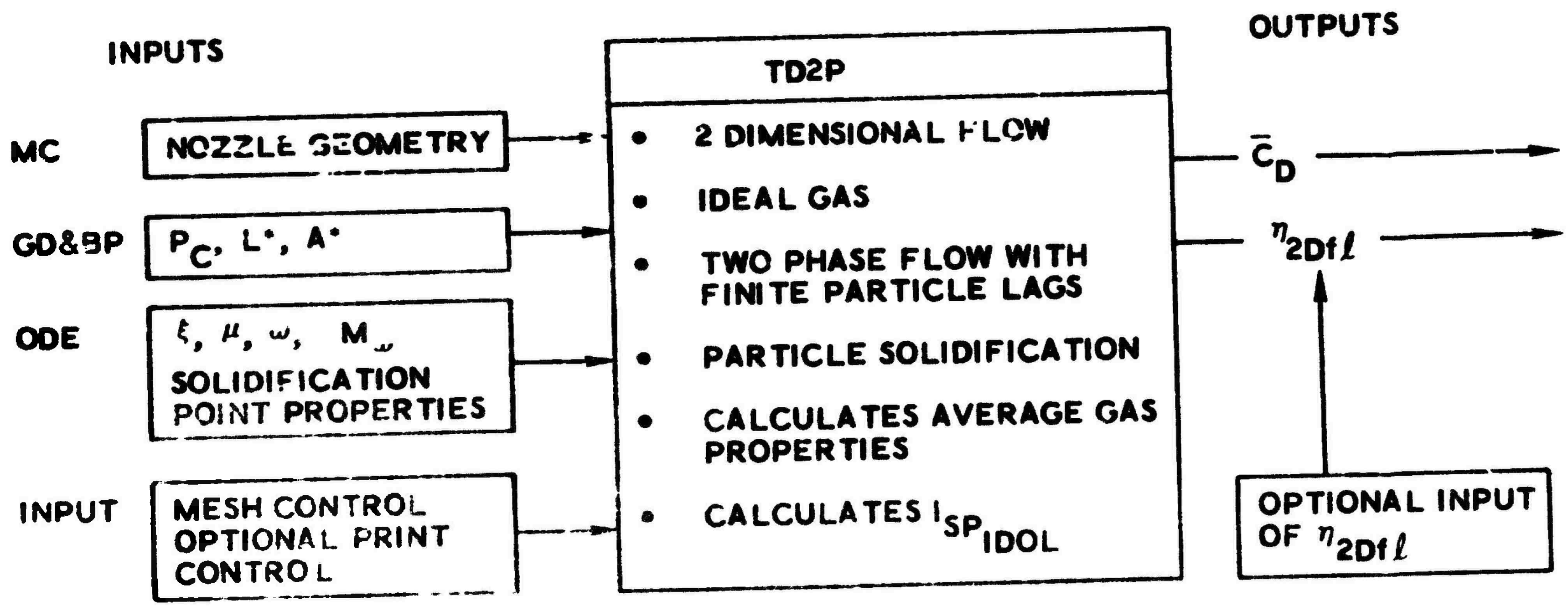


FIGURE 1-6 TWO DIMENSIONAL TWO PHASE FLOW CALCULATION MODULE (TD2P)

1) The TD2P module assumes that the gas phase flow behaves as an ideal gas. The gas phase properties are calculated by matching ideal one dimensional "equivalent" gas results to the output of the ODE module at the solidification point. In order that the condensed phase properties, and, hence, the results of the TD2P module, would not be artificially dependent on area ratio they were taken as the actual values obtained from the ØDE module.

2) The transport properties which are transmitted from the ØDE module are selected to insure the greatest degree of accuracy in the throat region.

3) The reference I_{sp} (one dimensional flow with zero lags, $I_{sp_{1DOL}}$), to which the TD2P I_{sp} is ratioed, is calculated using the same ideal gas properties as are used in the TD2P analysis. By using a ratio calculated in this manner, instead of using the absolute I_{sp} number from TD2P, the effect of neglecting real gas effects is minimized. Also, extra care was taken to accurately calculate the reference I_{sp} during solidification so as to avoid the use of different assumptions in the two modules.

4) The fact that the two phase flow loss tends to decrease with increased throat diameter (erosion) was intentionally ignored, since it was felt that the added loss due to throat roughness would more than compensate for this effect.

5) The transonic analysis currently incorporated into the TD2P module is restricted to running normalized throat radii of curvature of no less than approximately 1.5 and inlet angles less than about 45°. In addition the program requires the throat geometry to be circular with equal upstream and downstream radii of curvature. These restrictions on the geometries which may be realistically treated are a major shortcoming of the TD2P module.

6) The edge conditions which are generated by the TD2P module for the turbulent boundary layer, TBL, module have been adjusted so that the subsonic and transonic regions will faired into the supersonic regions in a smooth manner. The stagnation conditions transmitted to the TBL module have also been adjusted so as to allow the TBL module to reproduce the TD2P edge conditions (velocity, pressure) as closely as possible.

1.7 Turbulent Boundary Layer Module (TBL)

The losses associated with the presence of a boundary layer result from a transfer of heat to the nozzle walls and from a reduction in momentum due to shear stress along the walls. These losses can be calculated by properly integrating the stress tensor along the wall (pressure plus skin friction), or by calculating the momentum deficit in the boundary layer at the nozzle exit plane. The second method is the easiest to apply, and is the JANNAF recommended procedure.

The boundary layer development in the nozzle is currently computed using the Bartz-Silver integral method, as embodied in the JANNAF adopted TBL

program[4]. This is not the most accurate boundary layer program available, however, its virtues (speed and simplicity), coupled with the usually small magnitude of the loss (usually less tha 1% for all but small motors), make it a reasonable choice for the present purpose.

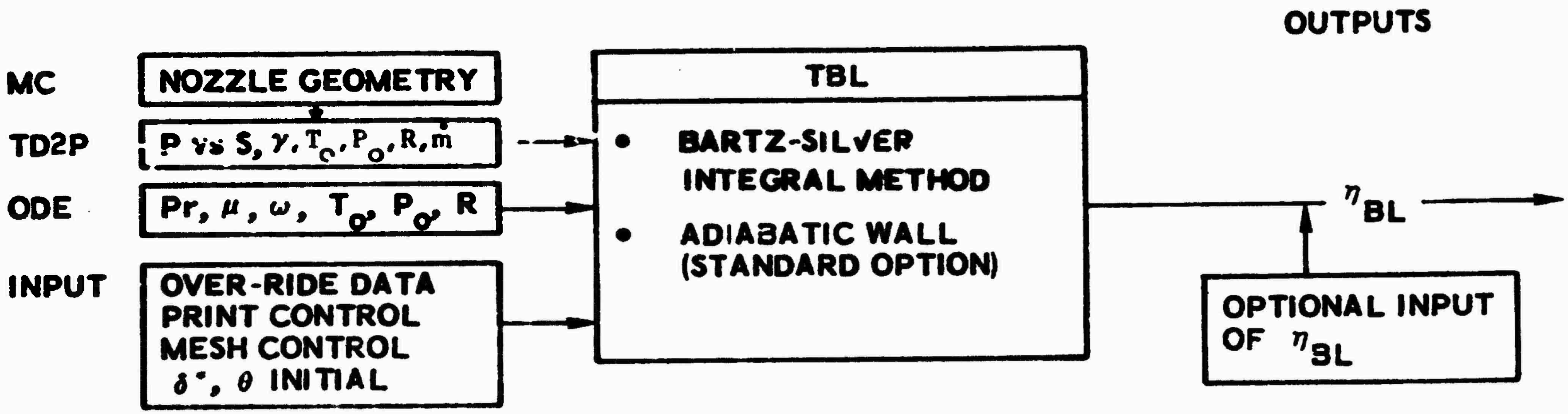
The boundary layer solution requires a specification of the inviscid flow along the wall streamline. In the SPP program these edge conditions are supplied automatically by the TD2P module (if executed). This allows the interaction between two dimensional and boundary layer effects to be properly accounted for. The TD2P module supplies the TBL module with the nozzle geometry, Mach number along the wall streamline, ideal gas properties, and stagnation pressure and temperature. This procedure allows the remaining edge properties to be computed internally in the TBL module (pressure, velocity, etc.) to match, as closely as possible, the respective TD2P computed counterparts.

The boundary layer loss is computed directly as an I_{sp} decrement, rather than as an efficiency, using the following formula

$$\Delta I_{sp_{BL}} = \frac{(2\pi r \rho u^2 \theta \cos \alpha)_e}{g \dot{m}_{TD2P}} \left[1 - \frac{\delta^*}{\theta} \frac{P_g}{\rho u^2}\right]_e ,$$

in which the various quantities are all evaluated at the nozzle exit plane. It should be pointed out that this equation gives the complete boundary layer loss. The reduction in fluid momentum due to shear and heat losses to the wall are both properly accounted for.

In most cases the effect of the invicid-viscous interaction between the TD2P and TBL modules is small and does not warrent the subsequent iteration which requires the re-running of TD2P module using the new invicid wall contour supplied by the TBL module. However, in extreme cases, the above procedure may be implemented by using the invicid wall contours supplied by the TBL module as input to second TD2P-TBL calculation. However, when boundary layer losses are of such importance that such effects should be considered, it is doubtful that the TBL analysis, and the assumptions incorporated within, are valid. Therefore, is is suggested that in these cases, that a more accurate method or analysis of the turbulent boundary layer loss be used.



$$\Delta I = - \frac{\left[2 \pi r \theta \ \rho_e U_e^2 \cos \alpha\right]}{g \dot{m}_{TD2P}} \left[1 - \frac{\delta^*}{\theta} \ \frac{g P_e}{\rho_e U_e^2}\right]$$

FIGURE 1-7 TURBULENT BOUNDARY LAYER LOSS MODULE (TBL)

That is to say, when the losses are small ($\lesssim$ 1/2%) even a poor characterization of the loss (± 50%) is acceptable. When the losses due to a turbulent boundary layer are large, then secondary effects (invicid-vicid flow interactions) are small compared to the primary boundary layer analysis loss. Hence, if the boundary layer loss is significant corrections made to the TBL module method of calculation are of minor importance since the overall method selected is of doubtful accuracy.

The input, internal linkages, characteristics, and output of the TBL module are schematically portrayed in Figure 1-7.

2. INPUT DESCRIPTION AND LINKAGE

The SPP Program is structured so that the various program elements which comprise the total performance prediction methodology can be utilized as an integrated set, as individual programs in a stand-alone mode, or in any user specified combination. The individual program modules have been combined with a control module which provides a means for inter-module communication. This allows the complete methodology to be executed automatically, with a minimum of user prepared input. Minimum is used here in the relative sense, as the amount of input required to perform all the analyses is not small.

Table 2-1 is essentially a block description and flow chart of the input data requirements of the SPP Program. In order to exercise the total program capability in a single run, one would have to consider the input requirements of all of the data sets listed in Table 2-1. The notes column of the Table indicates which data sets can be skipped if one desires to execute only a limited number of the program options. The subsection in which each of the data sets is described is also indicated in Table 2-1.

Table 2-1 should be used as a guide when preparing input for a given problem. It lists the data sets in the order in which they should appear in the data deck, and also shows the special cards which must appear in each set (first card, last card, etc.) if the program is to function properly. Table 2-1 is basically self-explanatory when used together with the detailed input descriptions which follow. The following additional notes are parenthetical.

1. Thermodynamic data will normally be on tape or on a mass storage permanent file. Card input will be required only when species not residing on the tape are considered.
2. Thermodynamic data below 300°K will rarely be required for solid rocket motor problems.
3. The Geometry data set is not optional if one desires the post-module execution summary outputs, or the final performance summary tables.
4. Figures 2-1 and 2-2 of Volume II can be very useful in understanding how and in what order data is transmitted between modules.

Section 2.11, following the input data descriptions, describes the internal (and external, via punch cards, perm. files, etc.) linkages between the basic computational modules of the program.

Table 2-1 Input Data Set Description

Data Set		card col. no. 1	2 3 4 5	6 7 8 9 10	Section Explaining Data Set	Notes
Title cards					2.1	1,2,3
	first card	T	I T L E	title information		
	last card			nono required		
Thermodynamic Data					2.2	3,4
	first card	T	H E R M	Ø		
	last card	E	N D			
Thermodynamic Data Below 300°K					2.2.1	1,3
	first card	L	Ø W T	C P H S		
	last card	E	N D L	Ø W T C P H S		
Geometry card					2.3	1,3
	first card	G	E Ø M E	T R Y		
	second card		$ G E Ø	M		
	last card		$ E N D			
Trajectory card					2.4	1,3
	first card	T	R A J E	C T Ø R Y		
	second card		$ T R A	J		
	last card		$ E N D			
Problem card					2.5	5
	first card	P	R Ø B L	E M		
	second card		$ P R Ø	B		
	last card		$ E N D			
Reactants card					2.6.1	12 6
	first card	R	E A C T	A N T S		
	last card			blank card required		
Omit and Insert cards					2.6.2	6
	first card	Ø	M I T			1
	last card			none required		
	first card	I	N S E R	T	2.6.3	1
	last card			none required		
ODE Namelist						6
	first card	N	A M E L	I S T S	2.6.4	
	second card		$ Ø D E		2.6.5	
	last card		$ E N D			
BAL Namelist					2.7.1	7
	first card		$ B A L			
	last card		$ E N D			
Ballistics input data					2.7.2	7
	first card	I	N I T I	A L		
	last card	E	N D Ø	F P R Ø G R A M		
Reactants cards					2.6.1	8
	first card	R	E A C T	A N T S		
	last card			blank card required		
Omit and Insert cards					2.6.2	8
	first card	Ø	M I T			
	last card			none required		
	first card	I	N S E R	T	2.6.3	
	last card			none required		

Table 2-1 (continued)

ØDE Namelists				
	first card	NAMELISTS	2.6.4	8
	second card	$ØDE	2.6.5	
	last card	$END		
ØDK option for input of Initial Species Concentrations			2.8.1	9
	first card	SPECIES		
	last card	none required		
Reactions			2.8.2	9
	first card	REACTIONS		
	last card	LAST REAX		
Inert Species Option			2.8.3	9
	first card	INERTS		
	last card	none required		
Third Body Reaction Rate Ratios			2.8.4	9
	first card	THIRD BØDY		
	last card	LAST CARD		
ØDK Namelist			2.8.5	9
	first card	$ØDK		
	last card	$END		
TD2P Namelist			2.9	10
	first card	$TD2P		
	last card	$END		
TBL Namelist			2.10	11
	first card	$TBL		
	last card	$END		

Notes

1 Optional.
2 More than one allowed.
3 May appear in any order before the PROBLEM card.
4 Optional, if a thermodynamic data already exists.
5 Mandatory.
6 Required only if the ODE option is selected.
7 Required only if the BAL option is selected.
8 Required only if restricted equilibrium option selected.
9 Required only if the ODK option is selected.
10 Required only if the TD2P option is selected.
11 Required only if the TBL option is selected.
12 If requested by input in the SPROB namelist, previously generated linkage data may be included after the SPROB namelist set (see Section 2.11).

2.1 TITLE CARDS

This input permits labeling of runs with alphanumeric information. As many title cards as desired may be input in sequence. Card format is as follows:

col 1-5	col 6-77
TITLE	any alphanumeric information

2.2 THERMODYNAMIC DATA

This data set is identical to the THERMO DATA described in Appendix D of NASA SP-273 (i.e. Reference 1).

Using this data set, thermodynamic data curve fit coefficients may be read from cards. The curve fit coefficients are generated by the PAC computer program described in NASA TN D-4097 (i.e. Reference 7).

The thermodynamic data (i.e. $C^\circ_{p_T}$, etc.) are expressed as functions of temperature using 5 least squares curve fit coefficients (a_{1-5}) and two integration constants (a_{6-7}) as follows:

$$\frac{C^\circ_{p_T}}{R} = a_1 + a_2T + a_3T^2 + a_4T^3 + a_5T^4 \qquad (2.2\text{-}1)$$

$$\frac{H^\circ_T}{RT} = a_1 + \frac{a_2T}{2} + \frac{a_3T^2}{3} + \frac{a_4T^3}{4} + \frac{a_5T^4}{5} + \frac{a_6}{T} \qquad (2.2\text{-}2)$$

$$\frac{S^\circ_T}{R} = a_1 \ln T + a_2T + \frac{a_3T^2}{2} + \frac{a_4T^3}{3} + \frac{a_5T^4}{4} + a_7 \qquad (2.2\text{-}3)$$

For each species, two sets of coefficients (a_{1-7} and a'_{1-7}) are specified for two adjacent temperature intervals, lower and upper respectively. For the data available in Reference 1 the lower temperature interval is 300° to 1000°K and the upper temperature interval is 1000°K to 5000°K.

The input format required for this thermodynamic data is defined in Table 2-2. Data cards for the species H, HO2, H2, H2O(L), H2O, H2O2, O, OH, O2, Al2O3(L), and AL2O3(s) are listed in Table 2-3 as examples. Thermodynamic data coefficients for 421 species are available in Reference 1 and are supplied with the computer program. A list of these 421 species names is presented in Table 2-4.

Data Tape Generation and Usage:

A computer run using thermodynamic data card input will generate a data tape on logical unit JANAF. This tape may then be saved and used at a later time.

The program writes the THERMO data card images on unit JANAF as read but with two minor exceptions. The THERMO code card and the card numbers in card column 80 are omitted.

If thermodynamic data cards are not input, the program assumes the thermodynamic data is on logical unit JANAF. Logical unit JANAF is currently assigned a value of 25.

TABLE 2-2 FORMAT FOR THERMODYNAMIC DATA CARDS

Card order	Contents	Format	Card column
1	THERMO	3A4	1 to 6
2	Temperature ranges for 2 sets of coefficients: lowest T, common T, and highest T	3F10.3	1 to 30
3	Species name	3A4	1 to 12
	Date	2A3	19 to 24
	Atomic symbols and formula	4(A2,F3.0)	25 to 44
	Phase of species (S,L, or G for solid, liquid, or gas, respectively	A1	45
	Temperature range	2F10.3	46 to 65
	Integer 1	I15	80
4	Coefficients a_i' (i = 1 to 5) in equations (2.2-1) to (2.2-3)	5(E15.8)	1 to 75
	(for upper temperature interval)		
	Integer 2	I5	80
5	Coefficients in equations (2.2-1)-(2.2-3) (a_6', a_7' for upper temperature interval and a_1, a_2, and a_3 for lower)	5(E15.8)	1 to 75
	Integer 3	I5	80
6	Coefficients in equations (2.2-1)-(2.2-3) (a_4,a_5,a_6,a_7 for lower temperature interval)	4(E15.8)	1 to 60
	Integer 4	I20	80
(a)	Repeat cards numbered 1 to 4 in cc 80 for each species		
(Final card)	END (Indicates end of thermodynamic data)	3A4	1 to 3

[a] Gaseous species and condensed species with only one condensed phase can be in any order. However, the sets for two or more condensed phases of the same species must be adjacent. If there are more than two condensed phases of a species their sets must be either in increasing or decreasing order according to their temperature intervals.

TABLE 2-3. SAMPLE THERMO DATA CARDS

(Species AR, H, H_2, H_2O, N_2, O, OH, O_2)

```
THERMO
   300.000   1000.000   5000.000
AR                  L 5/66AR  100   000   000   0G    300.000   5000.000             1
 0.25000000E 01 0.              0.              0.              0.                 2
-0.74537502E 03 0.43660006E 01 0.25000000E 01 0.              0.                   3
 0.              0.             -0.74537498E 03 0.43660006E 01                     4
H                   J 9/65H   100   000   000   0G    300.000   5000.000           1
 0.25000000E 01 0.              0.              0.              0.                 2
 0.25471627E 05-0.46011763E 00 0.25000000E 01 0.              0.                   3
 0.              0.              0.25471627E 05-0.46011762E 00                     4
H2                  J 3/61H   20    00    00    0G    300.000   5000.000           1
 0.31001901E 01 0.51119464E-03 0.52644210E-07-0.34909973E-10 0.36945345E-14        2
-0.87738042E 03-0.19629421E 01 0.30574451E 01 0.26765200E-02-0.58099162E-05        3
 0.55210391E-08-0.18122739E-11-0.98890474E 03-0.22997056E 01                       4
H2O                 J 3/61H   20    100   000   0G    300.000   5000.000           1
 0.27167633E 01 0.29451374E-02-0.80224374E-06 0.10226682E-09-0.48472145E-14        2
-0.29905826E 05 0.66305671E 01 0.40701275E 01-0.11084499E-02 0.41521180E-05        3
-0.29637404E-08 0.80702103E-12-0.30279722E 05-0.32270046E 00                       4
N2                  J 9/65N   20    00    00    0G    300.000   5000.000           1
 0.28963194E 01 0.15154866E-02-0.57235277E-06 0.99807393E-10-0.65223555E-14        2
-0.90586184E 03 0.61615148E 01 0.36748261E 01-0.12081500E-02 0.23240102E-05        3
-0.63217559E-09-0.22577253E-12-0.10611588E 04 0.23580424E 01                       4
O                   J 6/620   100   000   000   0G    300.000   5000.000           1
 0.25420596E 01-0.27550619E-04-0.31028033E-08 0.45510674E-11-0.43680515E-15        2
 0.29230803E 05 0.49203080E 01 0.29464287E 01-0.16381665E-02 0.24210316E-05        3
-0.16028432E-08 0.38906964E-12 0.29147644E 05 0.29639949E 01                       4
OH                  J 3/660   1H    100   000   0G    300.000   5000.000           1
 0.29106427E 01 0.95931650E-03-0.19441702E-06 0.13756646E-10 0.14224542E-15        2
 0.39353815E 04 0.54423445E 01 0.38375943E 01-0.10778858E-02 0.96830378E-06        3
 0.18713972E-09-0.22571094E-12 0.36412823E 04 0.49370009E 00                       4
O2                  J 9/650   20    00    00    0G    300.000   5000.000           1
 0.36219535E 01 0.73618264E-03-0.19652228E-06 0.36201558E-10-0.28945627E-14        2
-0.12019825E 04 0.36150960E 01 0.36255985E 01-0.18782184E-02 0.70554544E-05        3
-0.67635137E-08 0.21555993E-11-0.10475226E 04 0.43052778E 01                       4
END
```

Table 2-4. SPECIES WITH THERMODYNAMIC DATA PROVIDED

AL(S)	BCL	BEO(S)	C2H	FECL2(S)	KOH
AL(L)	BCL+	BEO(L)	C2HF	FECL2(L)	KOH(S)
AL	BCLF	BEO	C2H2	FECL2	KOH(L)
AL+	BCL2	BEOH	C2H4	FECL3(S)	K2
ALBO2	BCL2+	BEOH+	C2N	FECL3(L)	K2O(S)
ALCL	BCL2-	BEO2H2	C2N2	FECL3	LI(S)
ALCL+	BCL3	BE2O	C2O	FEO(S)	LI(L)
ALCLF	BF	BE2OF2	C3	FEO(L)	LI
ALCLF2	BF2	BE2O2	C3O2	FEO	LI+
ALCL2	BF2+	BE3O3	C4	FEO2H2(S)	LICL(S)
ALCL2+	BF2-	BE4O4	C5	FEO2H2	LICL(L)
ALCL2-	BF3	BR	CL	FEO3H3(S)	LICL
ALCL2F	BH	BR2(L)	CL+	FE2O3(S)	LIF(S)
ALCL3(S)	BHF2	BR2	CL-	FE3O4(S)	LIF(L)
ALCL3(L)	BH2	C(S)	CLCN	H	LIF
ALCL3	BH3	C	CLF	H+	LIF2-
ALF	BN(S)	C+	CLF3	H-	LIFO
ALF+	BN	C-	CLO	HALO	LIH(S)
ALF2	BO	CCL	CLO2	HBO	LIH(L)
ALF2+	BOCL	CCL2	CL2	HBO+	LIH
ALF2-	BOF	CCL3	CL2O	HBO2	LIN
ALF3(S)	BOF2	CCL4	CS(S)	HCL	LIO
ALF3(S)	BO2	CF	CS(L)	HCN	LIO-
ALF3	BO2-	CF2	CS	HCO	LIOH(S)
ALH	BS	CF3	CS+	HCO+	LIOH(L)
ALN(S)	B2	CF4	CSCL(S)	HCP	LIOH
ALN	B2O	CH	CSCL(S)	HF	LION
ALO	B2O2	CH2	CSCL(L)	HNO	LI2
ALO+	B2O3(L)	CH2O	CSCL	HO2	LI2CL2
ALOCL	B2O3	CH3	CSF(S)	H2	LI2F2
ALOF	B3O3CL3	CH4	CSF(L)	H2O(S)	LI2O(S)
ALOH	B3O3F3	CN	CSF	H2O(L)	LI2O(L)
ALOH+	BE(S)	CN+	CSO	H2O	LI2O
ALOH-	BE(L)	CN-	CS2	H2O2	LI2O2
ALO2	BE	CN2	CS2CL2	H2S	LI2O2H2
ALO2-	BE+	CO	CS2F2	H3B3O6	LI3CL3
ALO2H	BEBO2	COCL	CS2O	HE	LI3F3
AL2CL6	BECL	COCL2	E	HE+	MG(S)
AL2F6	BECL+	COF	F	K(S)	MG(L)
AL2O	BECLF	COF2	F-	K(L)	MG
AL2O+	BECL2(S)	COS	FCN	K	MG+
AL2O2	BECL2(L)	CO2	FO	K+	MGCL
AL2O2+	BECL2	CO2-	FO2	KCL(S)	MGCL+
AL2O3(S)	BEF	CP	F2	KCL(L)	MGCLF
AL2O3(L)	BEF2(S)	CS	F2O	KCL	MGCL2(S)
AR	BEF2(S)	CS2	FE(S)	KF(S)	MGCL2(L)
AR+	BEF2(L)	C2	FE(S)	KF(L)	MGCL2
B(S)	BEF2	C2-	FE(S)	KF	MGF
B(L)	BEH	C2CL2	FE(L)	KF2-	MGF2(S)
B	BEH+	C2F2	FE	K2F2	MGF2(L)
B+	BEN	C2F4	FECL	KO	MGF2

Table 2-4. (cont'd)

MGH	O	SIN
MGN	O+	SIO
MGO(S)	O-	SIO2 (S)
MGO(L)	OH	SIO2 (S)
MGO	OH+	SIO2 (S)
MGOH	OH-	SIO2 (L)
MGOH+	O2	SIO2
MGO2H2	O2-	SIS
N	P	SI2
NF	P(S)	SI2C
NF2	P+	SI2N
NF3	PCL3	SI3
NH	PF3	XE
NH2	PF5	
NH3	PH	
NO	PH3	
NO+	PN	
NOCL	PO	
NOF	PS	
NOF3	P2	
NO2	P4	
NO2-	S(S)	
NO2CL	S(L)	
NO2F	S	
N2	S+	
N2C	SF4	
N2H4	SF6	
N2O	SH	
N2O4	SN	
NA(S)	SO	
NA(L)	SOF2	
NA	SO2	
NA+	SO2F2	
NACL(S)	SO3	
NACL(L)	S2	
NACL	SI(S)	
NAF(S)	SI(L)	
NAF(L)	SI	
NAF	SI+	
NAF2-	SIC	
NAH	SIC2	
NAO	SICL	
NAO-	SICL2	
NAOH(S)	SICL3	
NAOH(L)	SICL4	
NAOH	SIF	
NA2	SIF2	
NA2CL2	SIF3	
NA2F2	SIF4	
NE	SIH	
NE+	SIH4	

2.2.1 THERMODYNAMIC DATA BELOW 300°K

For low temperature calculations it may be necessary to extend the curve fit data in the Thermodynamic Data file (see Section 2.2). The lower temperature limit, T_ℓ, in the Thermodynamic Data supplied with the program is

$$T_\ell = 300^\circ \text{ K}$$

Thermodynamic Data below the temperature, T_ℓ, may be input by data cards as described below.

	col 1↓	
card 1	LØW T CPHS	Directive for start of low temperature CPHS tables (col 1 through 10).
card 2	. . . . n	12 character species name, left justified followed by the integer, n, punched in column 21. The integer n must be such that $1 \le n \le 3$ and represent the number of Thermodynamic Data points to be input for this species.
card 3	T°_1K $C^\circ_{P_T}$ H°_T S°_T 1	First Thermodynamic Data point for the above species, input 4F 10.0, I5.
	⋮	
card n+2	T°_nK $C^\circ_{P_T}$ H°_T S°_T 2 nth $(1 \le n \le 3)$	nth Thermodynamic Data point for the above species, input 4F 10.0, I5.
. . .	Repeat cards 2 through n + 2 above for each species to be input. Temperature must be $T_1 < T_2 < T_3 < T_\ell$.	
(final card)	END LØW T CPHS	end directive (col 1 through 14)

An example of this input is given in Table 2-5 which shows a card listing extending the Thermodynamic Data for an O_2/H_2 propellant to 100°K. Data in Table 2-5 is taken directly from the JANAF tables (Reference 8), except for Argon which is taken from NASA SP-3001.

The quantity H°_T is defined as

$$H^\circ_T = (H^\circ - H^\circ_{298}) - \Delta H^\circ_{f_{298}} \quad , \quad \text{cal/mole}$$

$$C^\circ_{P_T} \quad , \quad \text{cal/mole - deg K}$$

$$S^\circ_T \quad , \quad \text{cal/mole - deg K}$$

TABLE 2-5 . LOW TEMPERATURE $C^{o}_{P_T}$, H^{o}_{T}, S^{o}_{T} DATA FOR AN O_2/H_2 PROPELLANT

```
LOW T CPHS
AR                         2
100.0      4.9681      -984.5       31.556        1
200.0      4.9681      -487.7       34.999        2
H                          2
100.0      4.968       51118.       21.965        1
200.0      4.968       51614.       25.408        2
H2                         2
100.0      5.393       -1265.       24.387        1
200.0      6.518       -662.0       28.520        2
H2O                        2
100.0     7.961       -59376.9    36.396          1
200.0     7.969       -58581.9    41.916          2
N2                         2
100.0      7.074       -1387.0      38.113        1
200.0      6.989       -684.        42.986        2
O                          2
100.0      5.666       58479.       32.466        1
200.0      5.434       59036.       36.340        2
OH                         2
100.0      7.567       7879.        35.852        1
200.0      7.309       8623.        41.021        2
O2                         2
100.0      6.958       -1381.       41.395        1
200.0      6.961       -685.        46.218        2
END LOW T CPHS
```

2.3 Geometry Directive and Input

The GEØMETRY directive allows the user to input the nozzle geometry in the $GEØM namelist set and have that information transmitted to the appropriate calculation modules. Any or all of the values input via the GEØMETRY directive may be overridden in the input to a specific calculation module.

The format of the GEØMETRY directive and description of the input is as follows:

The word GEØMETRY must start in card column 1 (Only the first 4 characters are checked). The card following the GEØMETRY card should contain $GEØM in card columns 2 through 6. The cards following the $GEØM card may be in any order up to the $END card which specifies the end of the geometry input data. All cards in the namelist input set must start in card column 2 or greater. The input items are

Item		Description	Units	Assumed Value(s)
$GEØM		namelist name		
ASUP(1)	=	supersonic area ratios at which information will be printed out	none	0.0
NASUP	=	number of entries in the ASUP array ≤ 40	none	0
ASUB(1)	=	subsonic area ratios at which information will be printed out	none	0.0
NASUB	=	number of entries in the ASUB array ≤ 10	none	0
NNØZ	=	number of nozzles	none	1
RSI	=	initial throat radius, r_i^*.	in	0.0
RCURV	=	normalized throat radius of curvature, r_c/r^*.	none	0.0
+RSDØT	=	nozzle erosion rate, $\dot{r}^*$.	mils/sec	0.0
+TBURN	=	motor burn time, used to calculate r^* as a function of time, i.e., $r^*(t)=r_i^*+\dot{r}^*t$.	sec	0.0

+These values will be overridden by the Grain Design & Ballistics Module calculated values if BAL=1 or 2 in $PROB Namelist.

Item		Description	Units	Assumed Value(s)
IWALL	=	wall specification option flag	none	0
	1	cone option (input THETA, RCURV, THETAI, RSI, and EPS)		
	2	parabolic nozzle contour option (input THETA, RCURV, THETAI, RSI, RMAX, ZMAX)		
	3	circular arc nozzle contour option (input-same as in IWALL=2)		
	4	nozzle contour (spline) option (input THETA, RCURV, THETAI, THE, RSI, RS, ZS, NWS)		

Note - Certain of the calculation modules (ØDK and TD2P in particular) contain more extensive nozzle geometry specification options than are presented here. However, the options cited above are applicable to all of the calculation modules in the SPP code.

The following items are illustrated in Figure 2.1 on the next page.

THETA	=	nozzle attachment angle	DEG.	0.0
THETAI	=	nozzle inlet angle	DEG.	0.0
THE		nozzle exit angle (input if IWALL=4 only)	DEG.	0.0
EPS		nozzle expansion ratio (input if IWALL=1 only)	none	0.0
RMAX		normalized radius at the nozzle exit plane (input if IWALL=2 or 3)	none	0.0
ZMAX		normalized axial position of the nozzle exit plane (input if IWALL=2 or 3)	none	0.0
RS(2)	=	table of normalized wall radii downstream of the nozzle tangency point. RS(1) is computed as r_T. (Input if IWALL=4)	none	0.0
ZS(2)	=	table of normalized axially positions downstream of the nozzle tangency point. ZS(1) is computed at Z_T (input if IWALL=4)	none	0.0

Item		Description	Units	Assumed Value(s)
NWS	=	number of entries in the RS, ZS tables. Includes the first entry. NWS ≤20. (Input if IWALL=4)	none	0
RZNØRM	=	Optional normalizing factor for the RS, ZS table. For example, if RS & ZS were input as dimensional numbers, RZNORM would be the throat radius in those units.	none	1.0
RI	=	normalized inlet wall radius of curvature. Only used if ØDK calculation selected. It is not necessary to input RI even if an ØDK calculation is to be made.	none	0.0
ECRAT	=	Contraction ratio at which the ballistics calculation will assume the nozzle inlet to start.	none	0
FSUBM	=	length of submergence/length of internal motor. (used in calculating the empirical submergence loss for the nozzle).	none	0.0
AEAS	=	nozzle entrance area/nozzle throat area (used in calculating the empirical submergence loss for the nozzle).	none	1.0
AVELS	=	motor average L*	in.	0.0
KNØZ	=	nozzle type flag =1 steel nozzle =0 all other types nozzle	none	0

$END

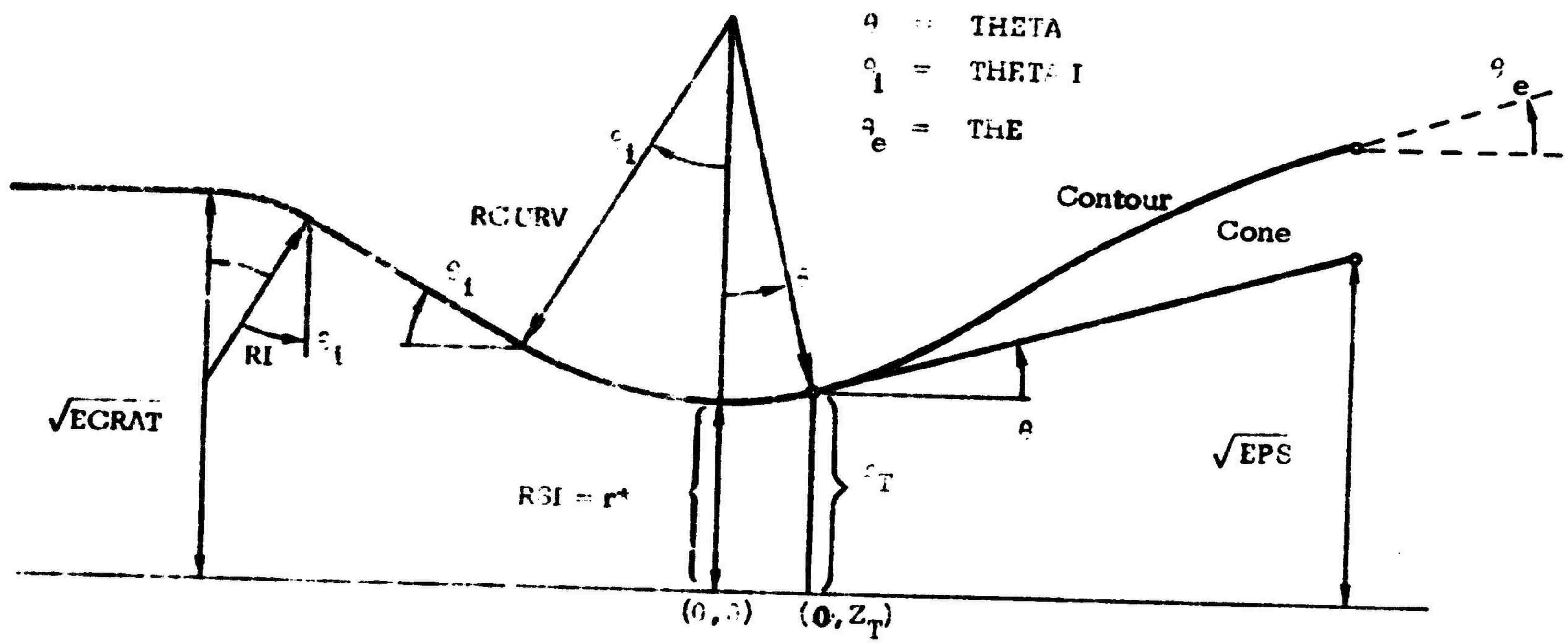


Figure 2-1 Nozzle Geometry

2.4 Trajectory Directive and Input

The TRAJECTØRY directive allows the user to input either the altitude or exhaust ambient pressure as a function of time during a motor firing in the $TRAJ namelist set. This data allows the SPP computer program to calculate the delivered performance at the actual motor conditions. If this input is not specified only vacuum performance can be calculated.

The format of the TRAJECTØRY directive and description of the input is as follows:

The word TRAJECTØRY must start in card column 1. (Only the first 4 characters are checked). The card following the TRAJECTØRY directive should contain $TRAJ in card columns 2 through 6. The cards following the $TRAJ card may be in any order upto the $END card which specifies the end of the trajectory input data. All cards in the namelist input set must start in card column 2 or greater. The input items are

Item		Description	Units	Assumed Value(s)
$TRAJ		namelist name		
PAMBI(1)	=	ambient pressure table	PSIA	0.0
H(1)	=	altitude table	FT.	
TTRJ(1)	=	times corresponding to the ambient pressure or altitude tables. Must be monotonically increasing in time.	sec.	0.0
NTJPT	=	number of entries to be used in the input tables. NTJPT≥ 1. If NTJPT=1, then the following is done: H(2)=H(1); PAMBI(2)=PAMBI(1); TTRJ(2)=1x10⁶.	none	0
IPH	=	0 - pressure table is to be used 1 - altitude table is to be used	none	0
$END		end of $TRAJ namelist set		

Note: The PAMBI and H arrays have been equivalenced to each other in order to save core storage. Hence, if both array names are input, the last input values will be used in accordance with the IPH flag.

2.5 Problem Directive and Input

The PRØBLEM directive and $PRØB namelist input allows the user to specify which calculation modules are to be executed and which losses are to be considered. The occurence of the PRØBLEM card and associated data in the input stream causes the selected loss modules to be executed in the sequence shown in Table 2.1.

The format of the PRØBLEM directive and description of the input is as follows:

The word PRØBLEM must start in card column 1. (All characters are checked). The card following the PRØBLEM card should contain $PRØB in card columns 2 through 6. The cards following the $PRØB card may be in any order up to the $END card which specifies the end of the problem input data. All cards in the namelist input set must start in card columns 2 or greater. The input items are

Item		Description	Units	Assumed Value(s)
$PRØB		namelist name		
ØDE	=	these input items call out the calculation modules which are to executed or specify how the data which would have generated by these modules is to be obtained. The allowable values for these variables are:	none	0.
CAL	=		none	0.
ØDK	=	0.0 either not considered or not executed.	none	0.
TD2P	=	1.0 module is to be executed.	none	0.
		2.0 data previously generated by module is to be read in on logical unit INP.		
TBL	=	3.0 values which would be generated by modules are to be read in.	none	0.
IREQ	=	0 kinetic start conditions for ØDK are to be read in via the SPECIES directive.	none	0
		1 kinetic start conditions for ØDK are to be computed from a 'restricted equilibrium ØDE calculation'. (see ECRAT in $ODE NAMELIST)		

Item		Description	Units	Assumed Value(s)
ETAI(I)	=	Input values of the loss mechanism efficiencies fractions. (Used only if module option =3. is selected)	none	1.0

I	Mechanism
1	finite rate kinetics
2	2 dimensional-2 phase flow
3	combustion efficiency
4	submergence
5	2 dimensional divergence loss

INP	=	Unit number on which previously generated data is to be read in on. (See Section 2.11)	none	3
$END	=	End of namelist set $PRØB		

2.6 ØDE INPUT DATA (ALL PROBLEMS SPECIFYING ØDE=1.0 OR IREQ=1)

The ØDE input data described here is as defined in NASA SP-273, Reference 1 , except namelists input $INPT2 and $RKINP have been combined into a single list named $ØDE. Only the rocket option (RKT in the namelist) is described here since all the other options have been removed from the ØDE calculation module.

The ØDE input data consists of the following input groups:

1.	REACTANTS	directive card, followed by up to 15 data cards, followed by a blank card, specifying reactants.
2.	ØMIT and INSERT	directives to omit or insert species for equilibrium/frozen calculations.
3.	NAMELISTS	directive card followed by input namelist $ØDE specifying input case data.

2.6.1 REACTANTS CARDS

This set of cards is required for all ØDE problems. The first card in the set contains the word REACTANTS punched in card columns 1 to 9. The last card in the set is blank. In between the first and last cards may be any number of cards up to a maximum of 15, one for each reactant species being considered. The cards for each reactant must give the chemical formula and the relative amount of the reactant. For some problems, enthalpy values are required. The format and contents of the cards are summarized in Table 2-6. A list of some REACTANTS cards is given in Table 2-7.

Relative amounts of reactants. - The relative amounts of reactants may be specified in several ways. They may be specified in terms of moles, mole fraction, or mole percent (by keypunching M in card column 53) or in terms of weight, weight fraction, or weight percent (blank in column 53).

Relative amounts of total fuel to total oxidants can also be input. For this situation, each reactant must be specified as a fuel or an oxidizer by keypunching an F or O, respectively, in column 72 of the REACTANTS card. The amounts given on the REACTANTS cards are relative to total fuel or total oxidant rather than total reactant.

TABLE 2-6. REACTANTS CARDS

Order	Contents	Format	Card columns
First	REACTANTS	3A4	1 to 9
Any	One card for each reactant species (maximum 15). Each card contains:		
	(1) Atomic symbols and formula numbers (maximum 5 sets)[a]	5(A2, F7.5)	1 to 45
	(2) Relative weight[b] or number of moles	F7.5	46 to 52
	(3) Blank if (2) is relative weight or M if (2) is number of moles	A1	53
	(4) Enthalpy or internal energy[a], cal mole	F9.5	54 to 62
	(5) State, S L, or G for solid, liquid or gas, respectively	A1	63
	(6) Temperature associated with enthalpy in (4)	F8.5	64 to 71
	(7) F if fuel or O if oxidant	A1	72
	(8) Density in g cm^3 (optional)	F8.5	73 to 80
Last	Blank		

[a]Program will calculate the enthalpy or internal energy (4) for species in the THERMO data at the temperature (6) if zeros are punched in card columns 37 and 38. (See section Reactant enthalpy for additional information.)

[b]Relative weight of fuel in total fuels or oxidant in total oxidants. All reactants must be given either all in relative weights or all in number of moles.

TABLE 2-7 LISTING OF SAMPLE REACTANTS CARDS

```
REACTANTS
H 2.                                            100.    0.         G298.15  F
N .7808810 .209795AR.004662                     100.    -7.202164G298.15  O


REACTANTS
N 1.     H 4.     CL1.     O 4.                 72.06   -70730.   S298.15  F
C 1.     H 1.869550 .031256S .008415            18.58   -2999.082L298.15  F
AL1.                                             9.00   +C.0      S298.15  F
MG1.     O 1.                                     .20   -143700.  S298.15  F
H 2.     O 1.                                     .16   -68317.4  L298.15  F


REACTANTS
H 2.                                  00        100.    0.        G298.15  F
O 2.                                  00        100.0   0.0       G298.15  O


REACTANTS
N 2.     H 8.     C 2.                          50.0    12734.8   L298.15  F  .786
N 2.     H 4.                                   50.0    12050.    L298.15  F 1.003
F 2.                                            100.    -3030.892L  85.24  O 1.54


REACTANTS
LI1.                                            100.    C.        S298.15  F
F 2.                                            100.    -3030.892L  85.24  O 1.54


REACTANTS
N 2.     H 4.                                   80.     12100.    L298.15  F 1.003
BE1.                                            20.     0.0       S298.15  F 1.85
H 2.     O 2.                                   100.    -44880.   L298.15  O 1.407
```

*Listed above are six examples. Each example must end with a blank card.

There are four options in the $ØDE namelist for indicating relative amounts of total fuel to total oxidant as follows:

1. Oxidant to fuel weight ratio (ØF is true).
2. Equivalence ratio (ERATIØ is true).
3. Fuel percent by weight (FPCT is true).
4. Fuel to air or fuel to oxidant weight ratio (FA is true).

For each option, except ØDE with ØDK≠1, and TD2P≠1, the values are given in the ØFSKED array of $ØDE (described in Section 2.6.4). For ØDE=1, ØDK≠1, and TD2P≠1, the MIX array is used as described in Reference 1.

Reactant enthalpy. Assigned values for the total reactant are calculated automatically by the program from the enthalpies of the individual reactants. Values for the individual reactants are either keypunched on the REACTANTS cards or calculated from the THERMØ data as follows:

Enthalpies are taken from the REACTANTS cards unless zeros are punched in card columns 37 and 38. For each REACTANTS card with the "00" code, an enthalpy will be calculated for the species from the THERMØ data for the temperature given in card columns 64 to 71.

When the program is calculating the individual reactant enthalpy for values from the THERMØ data, the following two conditions are required:

1. The reactant must also be one of the species in the set of THERMØ data. For example, NH_3(g) is in the set of THERMØ data but NH_3(l) is not. Therefore, if NH_3(g) is used as a reactant its enthalpy could be calculated automatically, but that of NH_3(l) could not be.
2. The temperature T must be in the range $T_{low}/1.2 \leq T \leq T_{high} \times 1.2$ where T_{low} to T_{high} is the temperature range of the THERMØ data.

For many cases it may be desirable to modify the enthalpy entered on the REACTANT cards. This can be done by using the DELH input array. The DELH entry will be added to the system enthalpy as computed by ØDE from the reactants cards (see above). For example, overall system enthalpy of the propellant can be input through the reactants cards and the energy added or extracted due to conditioning the propellant can be input by the DELH entry. An alternate method would be to input zero enthalpy on the Reactants cards and input enthalpy by the DELH entry.

The second and less important reason is that if one knows that one or several particular condensed species will be present among the final equilibrium compositions for the first assigned point, then a small amount of computer time can be saved by using an INSERT card. Those condensed species whose chemical formulas are included on an INSERT card will be considered by the program during the initial iterations for the first assigned point. If the INSERT card were not used, only gaseous species would be considered during the initial iterations. However, after convergence, the program would automatically insert the appropriate condensed species and reconverge. Therefore, it usually is immaterial whether or not INSERT cards are used. For all other assigned points the inclusion of condensed species is handled automatically by the program.

NOTE: For all metalized propellants it is strongly suggested that the appropriate condensed phases be included in the insert cards to insure convergence in the equilibrium calculation.

2.6.2 ØMIT and INSERT Cards

ØMIT and INSERT cards are optional. They contain the names of particular species in the library of Thermodynamic Data for the specific purposes discussed below. Each card contains the word ØMIT (in card columns 1-4) or INSERT (in card columns 1-6) and the names of from 1 to 4 species starting in columns 16, 31, 46, and 61. The names must be exactly the same as they appear in the THERMØ data.

2.6.2.1 ØMIT Cards

These cards list species to be omitted from the THERMØ data. If ØMIT cards are not used, the program will consider as possible species all those species in the THERMØ data which are consistent with the chemical system being considered. Occasionally it may be desired to specifically omit one or more species from considerations as possible species. This may be accomplished by means of ØMIT cards.

2.6.2.2 INSERT Cards

These cards contain the names of condensed species only. They have been included as options for two reasons.

The first and more important reason for including the INSERT card option is that, in rare instances, it is impossible to obtain convergence for assigned enthalpy problems (HP or RKT) without the use of an INSERT card. This occurs when, by considering gases only, the temperature becomes extremely low. In these cases, the use of an INSERT card containing the name of the required condensed species can eliminate this kind of convergence difficulty. When this difficulty occurs, the following message is printed by the program: "LOW TEMPERATURE IMPLIES CONDENSED SPECIES SHOULD HAVE BEEN INCLUDED ON AN INSERT CARD".

2.6.3 $ØDE NAMELIST INPUT

The ØDE subprogram contains namelist input sections $ØDE. The Namelist $ØDE must be preceded by a card with NAMELISTS punched in card columns 1-9.

The $ØDE Namelist is required for inputs to the $PRØB namelist set if:

ØDE = 1.0,

or

ØDK = 1.0,
IREQ = 1.

If both ØDE=1, and IREQ=1, are specified in the $PRØB namelist, two sets of ØDE data will be required.

The variables input by the $ØDE namelist are listed in Table 2-8. Additional information about some of these variables follows:

Pressure units. - The program assumes the pressure in the P schedule to be in units of atmospheres unless PSIA =.TRUE.

Relative amounts of fuel(s) and oxidizer(s). - These quantities may be specified by assigning 1 to 15 vlaues for either o/f, %F, f/a, or r. If no value is assigned for any of these, the program assumes the relative amounts of fuel(s) and oxidizer(s) to be those specified on the REACTANTS cards. (See discussion in REACTANTS Cards, Section 2.6.1).

RKT problem. - Only one value for chamber pressure, P, is to be input.

Print out will be given for the chamber pressure condition (i.e. stagnation) and the throat condition. Print out may be requested at other conditions by use of the PCP schedule and the SUBAR and SUPAR schedules. The values of ASUP and ASUB from the $GEOM namelist set will automatically be inserted into the SUPAR and SUBAR print arrays. Thus any input into these arrays will override the values input in the $GEØM namelist set for the ØDE calculation only.

The program will calculate both equilibrium and frozen performance unless FRØZ=F or EQL=F are input. If FRØZ=F, only equilibrium performance will be calculated. If EQL=F, only frozen performance will be calculated.

TABLE 2-8. VARIABLES IN $ØDE NAMELIST

Variable	No. of entries	Type	Value before read	Definition and comments
RKT	1	L	True	Rocket problem[a]
P(I)	25	R	0	Assigned pressures: stagnation pressures for rocket problems: values in atm unless PSIA, or SI= .T., (see below)
SI	1	L	False	[a]Values in P array are in N/m^2
PSIA	1	L	False	[a]Values in P array are in psia units
XP(I)	50	R	1.	Not currently used
ØF	1	L	False	Oxidant to fuel weight ratios are to be input[a]
ERATIØ	1	L	False	Equivalence ratios are to be input[a]
FPCT	1	L	False	Percent fuel by weight are to be input[a]
FA	1	L	False	Fuel to air weight ratios are to be input[a]
ØFSKED(I)	50	R	0	For a Rocket problem, and ODK= 1 or TD2P=1, ØFSKED will be used rather than MIX (see Reference 1). Relative amounts of total oxidant to total fuel are input as defined by ØF, ERATIØ, FPCT, or FA.
DELH(I)	50	R	0	This value will be added to the system enthalpy input thru the re-actants cards. Units are BTU/ # if PSIA=.T., otherwise cal/gram.
IØNS	1	L	False	Consider ionic species[a]
PCP(I)	50	R	0	Compute and print solutions at these ratios of chamber pressure to pres-sure (entries must be < 1.)
SUBAR(I)	50	R	0	Compute and print solutions at these values of subsonic area ratios (en-tries must $\neq 1$.)
SUPAR(I)	50	R	0	Compute and print solutions at these values of supersonic area ratio (en-treis must $\neq 1$.)

[a]If variable is set to be true.

[b]Set variable false if these calculations are not desired.

Table 2-8 (cont'd)

Variable	No. of entries	Type	Value before read	Definition and comments
ECRAT	1	R	0	Subsonic area ratio to start ØDK calculations with computed equilibrium conditions. The SUBAR input table must include an entry equal to ECRAT.[c]
EQL	1	L	True	Calculate rocket performance assuming equilibrium composition during expansion[b].
FRØZ	1	L	True[d]	Calculate rocket performance assuming frozen composition during expansion[b].
LISTSP	1	L	False	List names and dates of all species residing on thermodynamic data used[a].
KASE	1	I	0	Optional assigned number associated with case.
SØLPT	1	L	TRUE	For cases with condensed phases, the equilibrium conditions at the onset of solidification will be calculated.[b]
NLPRNT	1	L	FALSE	Write out the $ØDE namelist data set using a namelist write.[a]

[a] If variable is set to be true.

[b] Set variable false if these calculations are not desired.

[c] Required only for the restricted equilibrium option, i.e., IREQ=1 in $PRØB namelist.

[d] Assumed false for a restricted equilibrium calculation.

2.7 Grain Design and Ballistics Input

The input for this module is described in three parts. Section 2.7.1 describes the $BAL NAMELIST input, while Sections 2.7.2 and 2.7.3 describe the formated grain design and formated ballistics input, respectively.

2.7.1 $BAL NAMELIST

In the following list of input quantities an * preceding the variable name means that it is internally transmitted from the ODE module if ODE = 1 or 2 in the $PRØB NAMELIST (at present only values at one chamber pressure are transmitted to the BAL module from the ØDE module). Two ** are used to denote variables that are transmitted from the $GEØM NAMELIST, if used. Values input directly in $BAL will over-ride internally transmitted values.

Variable	Description	Units
*PC	Estimate of initial chamber pressure	lb/in^2
*CSTART	Theoretical C*	ft/sec
*TFT	Theoretical flame temperature	°K
*CPG	Specific heat of the gas only	Btu/mol/°R
*CPM	Specific heat of combustion products	Btu/mol/°R
*GAM	Ratio of specific heats	-
*XMG	Moles of gas per 100gm of products	mol/100gm
*XMM	Moles of products per 100gm of products	mol/100gm
*FCP	Moles of condensed phase per 100 gm of products	mol/100gm
*XMV	Gas viscosity	lb/in/sec
*XKG	Gas thermal conductivity	Btu/in/sec/°R
*XB	Nozzle erosion parameter, β	-
**RN(1)	Nozzle entrance radius	in
**RN(2)	Initial nozzle throat radius	in
**RN(3)	Nozzle exit radius	in
DTIME	Not used	
KBAL	Logical unit number for internal information transfer (set equal to 8 in MC module)	-
MODE	Integer used for control of internal information transfer. (Set equal to 0 in MC module)	-
**NNOZ	Number of nozzles	-

2.7.2 Grain Geometry Inputs

The data cards required to define the initial grain geometry are divided into two categories: (1) Initial data cards and (2) Figure cards. This input must be preceded by a title card. This title card is not used, however. The title card described in Section 2.1 is used instead.

2.7.2.1 Initial Data Cards

INITIAL is punched on the cards starting in column 1. These cards contain data which define the region in a coordinate system where the surfaces will be located plus data which control the limitations and X, Y and burn increments. The burn interval may be divided into a maximum of four sub-intervals; e.g., B0, B1, B2, B3, B4, where the Kth sub-interval (the interval defined by B_{K-1}, B_K) would be divided into NB_K parts. This may be desired where, for example, it is obvious that a complicated shape will burn into a simple shape, warranting a change in mesh size to save computer time.

The subscripting for X, NX and Y, NY is also identical* and is related to the burn intervals as follows: for each burn sub-interval, a complete set of X and Y values must be prepared, thus the reason for the double subscript on these quantities. The procedure for the first subscript is the same as for the burn and burn increments and the second subscript corresponds to the burn interval. To illustrate, suppose the burn interval is divided into two sub-intervals B0 to B1 to B2 with NB1 and NB2 parts; thus, two sets each of X and Y data are required, as follows:

Interval B0 to B1:

X01, X11, NX11, X21, NX21, X31, NX31 up to X41, NX41*

Y01, Y11, NY11, Y21, . . ., Y41, NY41

Interval B1 to B2:

X02, X12, NX12, X22, NX22, ..., X42, NX42

Y02, Y12, NY12, ..., Y42, NY42

---

*EXCEPTION: When the only burn interval is from B0 to B1 it is possible to have up to sixteen changes in the X interval. The subscripting on the X input would be as follows:

From one to nine interval changes:

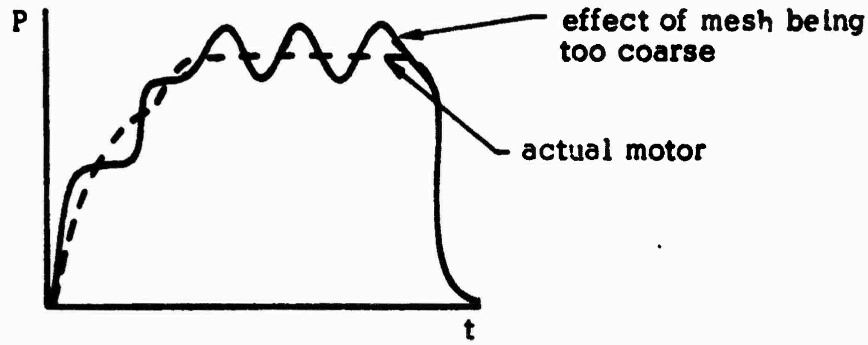
X01 X11 NX11 X61 NX61
X21 NX21 X71 NX71
X31 NX31 X81 NX81
X41 NX41 X91 NX91
X51 NX51

From ten to sixteen changes (continuing)

X03 NX23 X43 NX63
X13 NX33 X53 NX73
X23 NX43 X63 NX83
X33 NX53

where X01 = beginning X
X11 = ending X
NX11 = number of intervals in between X01 and X11
X21 = next ending X
NX21 = number of intervals in between X11 and X21
etc.

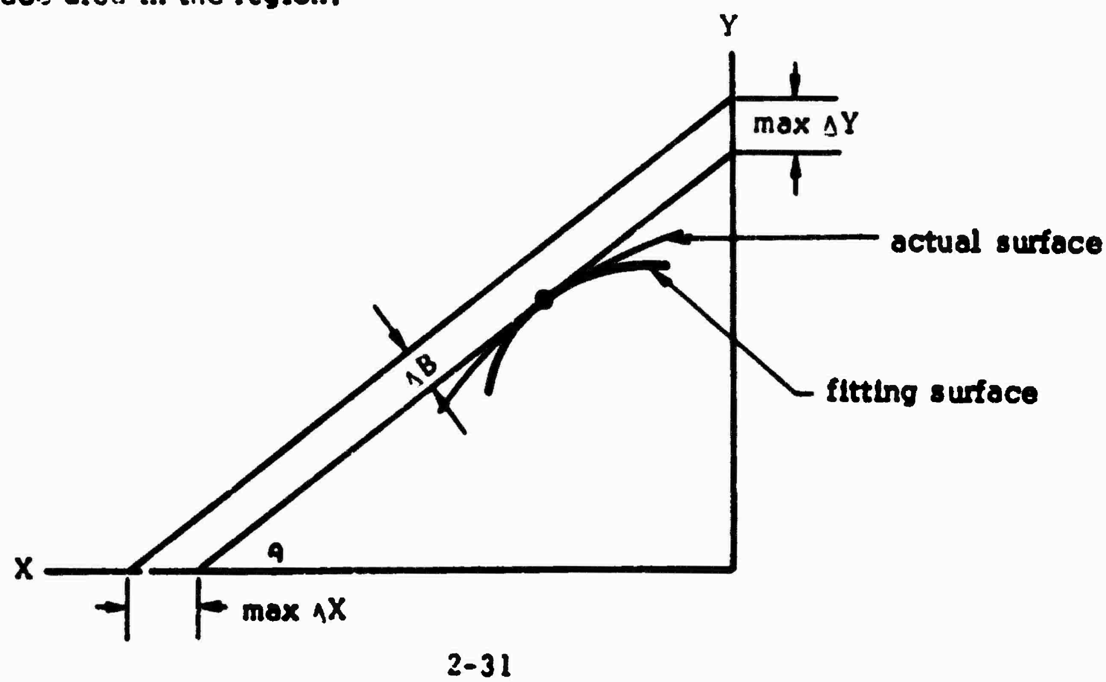
If too large a mesh size is specified a plot of surface area, or pressure, versus burn distance, or time, will reveal a saw tooth effect.



To avoid this situation the maximum X and Y increments should be based on the following criteria: the maximum X and Y increments, in order that a step or saw tooth effect in the plot of surface area or pressure versus burn distance or time is not obtained, are:

$$\max \Delta X = \Delta B \csc \theta$$
$$\max \Delta Y = \Delta B \sec \theta$$

where θ is the angle between the X axis and the line tangent to the point of intersection of the actual void and the representation figure that constitutes most to the surface area in the region.



It is not necessary for the number of increments of X and Y corresponding to the first burn interval to equal the number of increments of X and Y corresponding to the second burn interval and also for any more burn intervals. The restrictions on X and Y are that the initial and final values for X are equal and the initial and final values for Y are equal. To illustrate, suppose the following case:

For the interval B0 to B1:

X01 = 0.0
X11 = 5.0
NX11 = 10.0
X21 = 10.0
NX21 = 6.0

For the interval B1 to B2:

X02 = 0.0
X12 = 10.0
NX12 = 10.0

In this case X01 = X02 and X21 = X12. The same idea follows with Y.

The number of burn intervals must be a whole number, and the number of X and Y increments must be whole numbers, and the X and Y increments must be even whole numbers.

The burn interval, or sum of burn sub-intervals, constitutes the total propellant web. The number of burns, NB, determines the frequency of geometry output; thus, NB 20 will yield answers for each 5% of web burned. This is not to be confused with NX or NY, which define the calculational mesh at a given time or web burned, or with separate control of ballistics output.

The computational time will be proportional to the product of the number of X and Y increments. In other words, if both are doubled, the time will increase by roughly a factor of 4.

2.7.2.2 Figure Cards

The first card for each surface contains the names of the figure starting in column 1. The cards immediately following contain the data defining the figure and how it will burn. The first card contains information of whether the figure is to consist of propellant or void. If the figure is to consist of propellant, a CR is punched in columns 19-20 and the figure is considered to burn inward; otherwise

the figure is considered void and burns outward.

The burning of the figure is controlled on a BURN card. A figure may burn in any combination of the following types of burning. (This card is used only if a figure is to be burned in a special manner.)

Type Burn	Variables Name Columns	Value Columns	Burn Considered	Action
Nonburning	NB		Burn = 0.0	No burning occurs in the figure.
Delayed burn	DB	a	Burn = B-a	The figure is delayed in burning the specified amount (a).
Rated burn	RB	b	Burn - (B)(b)	The figure is burned b times as fast (or slow) as the normal burn.
Corner rounding	CR	c	---------	The figure (prism, cone or cylinder) is backed-up the distance c and then burned out again the distance.

The data defining the figure is contained on the DATA cards. Punched in columns 1-4 of these cards is the word DATA. These cards will contain the control characters X1, X2, X3, Y1, Y2, Y3, Z1, Z2, Z3, R, R1, R2, H. The X, Y, and Z characters define points in an X, Y and Z coordinate system. R is the radius and H is for prism height. In the case of a cone, where two radii are required, R1 and R2 are used. When R1=R2; e.g., in a cylinder, the R is used, which will cause the same value to be stored in R1 and R2.

The figures the program will handle and their inputs are:

Cone (right)	Two points (the center of two bases)	X1, Y1, Z1 X2, Y2, Z2
	Two radii (the radius of the two bases) (R1 is radius at point 1 and R2 is radius at point 2)	R1, R2
Cylinder (right)	Two points (the center of the two bases)	X1, Y1, Z1 X2, Y2, Z2
	One radius (the radius of the cylinder)	R

Prism (right triangular)	Three points (corners of bisecting plane)	X1, Y1, Z1 X2, Y2, Z2 X3, Y3, Z3
	Height of prism	H
Sphere	One point (center of sphere)	X1, Y1, Z1
	Radius of sphere	R

2.7.2.3 Propellant Periphery and Exposed Insulation

The complete description of the motor geometry requires a series of cards in the form of a table of outer propellant radius versus axial position. The X convention should be consistent with that describing the configurations above, but the number of entries need not be consistent with NX. Only the extremities in X need be consistent with those on the initial *INIT) cards. Up to 100 entries are allowed; however, far fewer will generally suffice.

Insulation area exposed as the web burns is not computed, but may be input in the form of a table. (See Section 2.7.3, Table 2-10)

2.7.3 Ballistics Inputs

2.7.3.1 Input Scheme

Following the last card containing grain design information, but preceding the ballistics input, a card containing the word COMPUTE, starting in card column 1, must appear.

The ballistics input is controlled from subroutine TABIN, but is actually read in subroutine DATAIN, in the following sequence:

1 TABLES OF DATA
o
o
o
o
TABLE
COMPLETION CODE

2 INTEGER INPUT WORDS
SET COMPLETION CODE

3 DATA INPUT WORDS
SET COMPLETION CODE

RETURN TO READIN

↓

4 TRANSFER N-Z WORDS TO WORKING REGION

↓

5 DATA INPUT WORDS SET COMPLETION CODE

↓

RETURN TO MAIN3

All of the data tables (1) are read first, with a limit of 50 tables and 3000_{10} words of storage, both about three times more than normal input for one case. The tabular input is assumed to continue until a READ IN completion code (loc. 4=-1) is given. The input in the remaining two sets (2) and (3) is then interpreted in the program. Integer words (2) are logic controls for the calculation, and data words (3) include coefficients, constants, and some problem logic control words, to be described in detail in subsection 2.7.3.2.

The input is transferred to working storage in the main program (4) if non-zero (nz) values are given. As a result, only changes in the problem are needed in successive cases. Also, only input pertinent to the case and options to be used is required, so unneeded input can be completely ignored. Since zero input is ignored, no "filling" is required, but values in the cards do no harm if desired for column alignment, etc. One limitation in the method is that options can not be "turned off" by inputting a zero in a later card. The node points are derived from the NX values in the grain design input. Points defining radial slots include one point at the end of each grain segment and one (only one) in the slot. The number of NX increments is given as -2.0 for the special case of a radial slot to key the logic. Once accomplished, the number is made positive and the grain design program operates as usual.

2.7.3.2 Details of Input

In this subsection, the mechanics of card format and table input are considered; then the parameters and requirements are specified.

<u>Format</u>

Three card input formats are used by the program,

4 (I2, I4, 6X), I2, 28A	Logic, first of set
6 (I2, I4, 6X), I2	Logic, remaining cards in set
6 (I2, F10), I2	Data

For either logic (integer) words or data cards, the input is interpreted as (loc for location).

1-2	3-12	13-14	---
loc,	input value	loc	---
I2,	I4, 6X or F10	I2	---

The input cards are read in sets, and a set is assumed to continue until a completion sign is encountered. Two completion signs are recognized:

(i) A blank card

(ii) A negative location, i.e., location = -1 in any of the I2 fields on the card

Note that the completion sign for the group of tabular inputs is different in meaning and form ($_b4_{bb}$ $_{-1}$ in I2, I4).

Rules governing the interpretation of a card set include:

Any number of cards may form a set

Any order of locations is acceptable

Zero values of input are ignored

If locations are repeated, the last value of input is used (overwrites)

If a location is blank but data is given, a sequenced list is assumed, so the following two cards are equivalent:

1	10.	2	11.	3	12.	-1
1	10.		11.		12.	-1

The sequencing does not follow from card to card, so the first location on the next card must be given.

Tabular Data

Data tables are assumed of the form z=f (x, y). Tables are termed rectangular if the number of x arguments in the rows is the same for each of the columns of y arguments. A non-rectangular table, then, has a varying number of x arguments in the columns.

The card sets to input a table are given in Table 2-9 with the location

Table 2-9 Input of Tabular Data

Input for Form Z = f (X, Y)

Input Type	Input	Description
Integer card set	Required	Control constants
Data card set	Required if NY > 1 Omit if NY=1	Y values
Data card sets	1 set if rectangular NY sets if nonrectangular	X values
Data card sets	NY sets required	Z values

Integer Cards 4 (I2, I4, 6X), I2, 28A; 6(I2, I4, 6X) I2

Location	Input	Description
1	Required	Table number (see Table 2-10)
3	Optional	Key to LOG-LOG interpolation (+)
4	Optional	Table type non-rectangular = (+) (Note that (-) is key to end table inputs)
5	Optional	Number of Y (columns) values, required if NY > 1
6	Optional	Number of X (rows) values, required if NX > 1
7 to 25	Optional	Number of X values in 2nd ---- 19th Y columns, non-rectangular tables

Data Card Sets 6 (I2, F10), I2

Location	Input	Description
1	Optional	List of X, Y, or Z values sequenced from Location 1
Any	Required	Completion sign

NOTES:

1. A table can degenerate to one point in X, Y, or both.
2. Interpolation is linear with no extrapolation: values at boundary of table are returned.
3. A missing table causes Z=0 and one (only one) error message.

of the words in the sets. The logic (integer) card set is always required and must include a table number and a completion sign. The number of y columns (NY) in location 5 and x rows (NX) in location 6 must be given if more than one. Location 3 is used to key log-log interpolation if desired, and a (+) value in location 4 keys a nonrectangular table.

Usually, one set of y values, one set of x values, and NY sets of z values compose a table. If only one column is specified, the set of y values is omitted. If a non-rectangular table is specified, the number of x values in each column must be given, starting in location 7, and an x argument set is required for each y argument.

Assignment of Input Tables

The numbers of input data tables are assigned in the subroutine MAIN3 due to compiled-in constants in the call statement:

CALL TAB (X, Y, Z, NO)

The correspondence of input data and the table numbers, NO is given in Table 2-10 with the FORTRAN symbol and assumed arguments of the tables. In Table 2-10, data that is designated as "optional" is needed only if the related option is specified. Data that is designated as required is almost always needed since zero values of the parameter (Z) are rarely meaningful; the possible exception is the list of times of detailed output where no input results in printout at all time steps.

Integer Inputs

A series of integer words may be input to control program options, as shown in Table 2-11. Loc (4)=NUM(4)=-1 is the required input to indicate the end of data tables. The node number of each radial slot is required input. Other input in Table 2-11 is used only if the particular option is desired.

Data Input Words

Up to 99 data (real) word locations are provided to complete the input constants and control options in the program, as listed in Table 2-12. Note that one data set is used, regardless of the number of cards, as discussed earlier.

Table 2-10 Input Table Assignments

Table No.	Function	Input	Z Symbol	X	Y
1	Propellant strand burning rate at conditioning temp.	Required	RO	P(I)	-
2	Pressure exponent	Required	SLOPE	P(I)	-
3	Motor geometry (grain outer radius)	Required	R(1)	X123	-
4	Insulation area	Optional	AI	TIME	-
5	Time increments	Required	DT	TIME	-
6	Time of detailed output	Required	TLIST	TIME	-
7	Throat area table	Optional	AP (NN); KODE=5	TIME	-
8	Slot burn rate correction	Optional	DR	WEB(I)	X(I)
13	Slot diameter	Optional	DSLOT	TIME	AFI(L)
14	Slot burn-back correction	Optional	DX	WEB(I)	AFI(L+10)

Table 2-11 Integer Input Parameters

Location	Symbol	Input	Description
Num (4)	-	Required	(=-1) indicator of end of tables
Num (5)	Ign	Optional	Key (+) for ignition dt option
Num (11-20)		Optional	Node number of radial slots
Num (21-30)		Optional	Propellant number for following segment

Table 2-12 Data Input Parameters

Location	Symbol	Units	Input	Description
Z(1)	TSTOP	sec.	Required	Calculation run (expected burn) time
Z(2)	TRISE	sec.	Optional	Time of rapid pressure rise (ignition rise), an aid to convergence
Z(3)	CONV	--	Required	Convergence ratio (.00005-.005)
Z(6)	PAMB	lb/in^2	Required	Ambient pressure
Z(7)	KODE	--	Required	Nozzle material 1. carbon phenolic 2. ATJ Graphite 3. pyrolytic graphite 4. non-eroding 5. a table of erosion rate is to be input
Z(8)	KODE 1	--	Required	1. if fully insulated motor 2. if uninsulated
Z(9)	KODE 2	--	Required	Binder type 1. PBA Binder 2. HTPB Binder 3. CTPB Binder 4. NC Binder 5. PU Binder 6. PGA/NC Binder 7. NF Binder
Z(10)	ALUM	per cent	Required	Aluminum concentration
Z(11)	MMO	gm/mole	Required	Molecular wt. metal oxide
Z(12)	TAMB	°K	Required	Ambient temperature
Z(13)	FACTOR	--	Required	Loop gain ratio
Z(14)	PSTART	lb/in^2	Required	Trial value of motor pressure
Z(15)	ETAF	fractional	Required	Nozzle efficiency; 1.000 in the integrated mode
Z(16)	RHO	lb/in^3	Required	Propellant density
Z(17)	RHOI	lb/in^3	Optional	Insulation density
Z(18)	RI	in/sec	Optional	Insulation ablation rate
Z(19)	ANOZ	in^2	Optional	Projected nozzle surface area for reradiation to propellant
Z(20)	ETAIN	fractional	Required	Recovery efficiency for radial slots

Table 2-12 Data Input Parameters (Continued)

Location	Symbol	Units	Input	Description
Z(21)	C1	in/sec	Required	Erosive burning constant
Z(22)	C2	--	Required	Erosive burning exponent
Z(23)	RHOAMB	lb/in^3	Required	Ambient gas density
Z(24)	CS	BTU/lb°R	Required	Heat capacity of propellant
Z(25)	TSUR	°K	Required	Propellant surface temperature (850 for AP-composite, 520 for double-base)
Z(26)	ALPHA	in^2/sec	Required	Propellant thermal diffusivity
Z(41)-Z(50)	AF	--	Optional	Key word for radial slot ignition, 10 forward faces, 10 aft faces (value = ignite)
Z(71)-Z(80)	AFI	in	Optional	Table argument value for up to 10 radial slot ignition diameter inputs (key to input table number 13). Ignited diameter becomes required input if slot face is burning.
Z(91)-Z(100)	---	--	Optional	Key word to suppress pressure rise down the port. Requires definition of slots and segments to function.

Termination of Ballistics Data Set

Following the last card containing ballistics input a card containing the words END ØF PRØGRAM, beginning in card column 1, must be inserted.

2.8 ØDK INPUT DATA

ØDK input data is required only in ØDK = 1 as specified in the $PRØB namelist set.

2.8.1 SPECIES

Species used by the computer program are determined in several possible ways, depending upon the problem type. Methods used to determine chemical species for each problem type are discussed below.

ØDK = 1, IREQ = 0

For ØDK problems, species names and concentrations must be input, see Section 2.8.1.1

ØDK = 1, IREQ = 1

For ØDE (restricted) - ØDK problems, the initial start conditions for the kinetic expansion are obtained from a restricted equilibrium calculation. The species list generated by the equilibrium calculation generally contains many more species than the 40 species for which the ØDK subprogram is dimensioned. Therefore a selection process is required to interface the ØDE calculated equilibrium start conditions with the ØDK kinetic expansion calculations. This selection is performed using the following rules:

Rule 1 If a species appears in a reaction, it is selected for the kinetic calculation.

Rule 2 If a species is specified using INERTS directive it is selected for the kinetic calculations.

Rule 3 If any species has a mole fraction greater than an input criterion, it is selected for the kinetic calculation.

Species which are selected but which do not appear in a reaction are treated as inert and listed as such on the output list of selected species.

2.8.1.1 ØDK OPTION FOR INPUT OF INITIAL SPECIES CONCENTRATIONS (APPLIES TO THE ØDK ONLY PROBLEM)

This input begins with a single card with SPECIES in columns 1 through 7 and with either MASS FRACTIØNS or MØLE FRACTIØNS in columns 9 through 22. If the identifier for mass or mole fractions is omitted, mass fractions are assumed. Up to 40 species cards may be input. Only those species specified by input species cards will be considered for an ØDK problem. The order of the input species cards is independent of the order in which the species appear on the master Thermodynamic Data file.

A chemical species is identified symbolically by 12 alphanumeric characters and must correspond identically with the species name as it appears on the Thermodynamic Data file. A complete list of the current species names are listed in Table 2-4. The species symbol may not contain the characters * or =.

Col	Function
1-10	Not used
11-22	Species symbol (left-justified)
23-30	Not used
31-60	Value of initial species concentration (if zero must be input as 0.0) free field F or E format
61-80	User Identification if desired

2.8.2 REACTIØNS

Chemical reactions must be input for an ØDK problem.

Up to 50 reactions with an implied third body and a total 150 reactions may be input to the program. Only one card per reaction, and only one reaction per card is permitted. Cards specifying third body reactions must precede cards specifying all other reactions. Species names appearing in the symbolic reaction set must correspond identically with the species names as they appear in the master Thermodynamic Data (see Table 2-4). A card listing for a sample reaction set is presented in Table 2-13.

Table 2-13 Sample Aluminized Propellant Reaction Set

```
REACTIONS
 CO + O  =     CO2  , A=5.05E15,  N=0.  ,  B=2.5,              BAULCH (1968)L1
 CL2     =  CL + CL , A=2.E13,    N=0.  ,  B=46.450,           SOLOMON(1971)
 HCL     =   H + CL , A=6.86E21,  N=2.  ,  B=102.17,           JACOBS (1966)
 HO2     =   H + O2 , A=2.40E15,  N=0.0 ,  B=45.9 ,     NO.36 BAULCH (1969)
 H2      =    H + H , A=7.0E12,   N=-.50,  B=92.60,     NO.3 BROKAW   (1974)
 H + OH  =      H2O , A=3.0E19,   N=1.00,  B= 0.00,     NO.5  PREHN   (1967)
 O2      =    O + O , A=2.85E19,  N=1.00,  B=118.7,     NO.1 JOHNSTON (1968)
 ALCL+ CL   = ALCL2        , A=3.0E16  ,N= 0.5   ,B= 0.0   ,          31
 ALCL2+CL   = ALCL3        , A=3.0E16  ,N= 0.5   ,B= 0.0   ,          32
 ALCL+ O    = ALOCL        , A=3.0E16  ,N= 0.5   ,B= 0.0   ,          41
AL + H = ALH ,        A=  3.0E16 , N=  0.5 , B=  0.0, ESTIMATE
H + ALO2 = ALO2H ,    A=  3.0E16 , N=  0.5 , B=  0.0, ESTIMATE
OH + ALO = ALO2H ,    A=  3.0E16 , N=  0.5 , B=  0.0, ESTIMATE
ALO + H = ALOH ,      A=  3.0E16 , N=  0.5 , B=  0.0, ESTIMATE
END TBR REAX
 CO +CLO = CO2 + CL , A=1.E11  ,  N=-.5 ,  B=3.5,              ESTIMATE
 CO + O  =     CO2  , A=1.78E10,  N=0.  ,  B=2.53,             BAULCH (1968)L1
 CO + OH = CO2 + H  , A=5.6E11 ,  N=0.  ,  B=1.08,             BAULCH (1968)L1
CO2 + H2 =  CO +H2O , A=9.5E8  ,  N=-.5 ,  B=15.,              TINDER (1967)
 CO2+ O  = CO  + O2 , A=1.9E13 ,  N=0.  ,  B=54.15,            BAULCH (1968)L1
 CL + HO2= CLO + OH , A=5.E11  ,  N=-.5 ,  B=3.5,              ESTIMATE
 CL + HO2= HCL + O2 , A=5.E11  ,  N=-.5 ,  B=2.6,              ESTIMATE
 CL + H2 = HCL + H  , A=1.2E13,   N=0.  ,  B=6.3,              WESTONBERG (68
 CL + OH = HCL + O  , A=2.0E11,   N=-.67,  B=.1   ,            MAYER  (1967)
 CLO+ H  = HCL + O  , A=5.E11  ,  N=-.5 ,  B=3.56,             ESTIMATE
 CLO+ O  =  CL + O2 , A=5.E11  ,  N=-.5 ,  B=3.56,             ESTIMATE
CL2 + H  = HCL + CL , A=3.0E14,   N=0.  ,  B=3.0,              CHERRY (1967)
CL2 + O  = CLO + CL , A=5.E11  ,  N=-.5 ,  B=3.2,              ESTIMATE
 HCL + OH= H2O + CL , A=1.0E11,   N=-.5 ,  B=5.0  ,            CHERRY (1967)
 H2 + O  =   H + OH , A=2.9E13,   N=0.00,  B= 9.80,     NO.19 BRABBS  (1970)
 H2 + OH =  H + H2O , A=2.19E13,  N=0.00,  B= 5.15,     NO.20 BAULCH  (1968)
 NO + NO =  N2 + O2 , A=1.E13  ,  N=0.  ,  B=76.0,             BAULCH (1969)L6
 OH + OH =  O + H2O , A=5.75E12,  N=0.00,  B= 0.78,     NO.21 BAULCH  (1968)
 O2 + H  =   OH + O , A=1.66E14,  N=0.00,  B=16.40,     NO.18 BELLES  (1970)
 ALO   + CO     = AL     + CO2   ,A=1.0E11,N=-.5      ,B= 3.215 ,           217
 ALO   + O      = AL     + O2    ,A=5.3 E11,N=-.5     ,B= 3.215 ,           220
 AL2O  + CL     = AL     + ALOCL,A=1.0E11,N=-.5       ,B= 3.621 ,           221
 AL    + OH     = ALO    + H     ,A=5.3 E11,N=-.5     ,B= 2.632 ,           226
 ALO   + ALCL   = AL2O   + CL    ,A=1.0E11,N=-.5      ,B= 3.269 ,           229
 ALCL2+ H       = ALCL   + HCL   ,A=1.0E11,N=-0.5     ,B=2.566  ,           232
 AL    + CL2    = ALCL   + CL    ,A=5.3 E11,N=-0.5    ,B=1.6    ,           235
 AL    + HCL    = ALCL   + H     ,A=5.3 E11,N=-0.5    ,B=2.859  ,           236
 ALO   + CL     = ALCL   + O     ,A=5.3 E11,N=-0.5    ,B=2.859  ,           237
 ALO   + ALCL2  = ALCL   + ALOCL,A=1.0E11,N=-0.5      ,B=2.566  ,           240
 ALCL  + CL2    = ALCL2  + CL    ,A=1.0E11,N=-0.5     ,B=1.     ,           242
 ALCL  + CO2    = ALOCL  + CO    ,A=1.0E11,N=-0.5     ,B=1.520  ,           243
 ALCL2+ OH      = ALOCL  + HCL   ,A=[illegible].17E11,N=-0.5  ,B=27.603 ,   244
 ALO   + CL2    = ALOCL  + CL    ,A=1.0E11,N=-0.5     ,B=1.6    ,           245
 ALCL2+ O       = ALOCL  + CL    ,A=1.0E11,N=-0.5     ,B=2.566  ,           246
 ALO   + HCL    = ALOCL  + H     ,A=1.0E11,N=-0.5     ,B=2.859  ,           247
 ALCL  + OH     = ALOCL  + H     ,A=1.0E11,N=-0.5     ,B=2.859  ,           248
 ALCL  + O2     = ALOCL  + O     ,A=1.0E11,N=-0.5     ,B=3.208  ,           249
 ALCL2+ ALCL2   = ALCL   + ALCL3,A=1.0E11,N=-0.5      ,B=2.566  ,           306
 ALCL2+ CL2     = ALCL3  + CL    ,A=1.0E11,N=-0.5     ,B=1.6    ,           311
 ALCL3+ H       = ALCL2  + HCL   ,A=1.0E11,N=-0.5     ,B=2.591  ,           318
ALO + OH = ALO2 + H ,          A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALO + CLO = ALO2 + CL ,        A=  1.0E11 , N= -0.5 , B=  3.6165, ESTIMATE
ALO + O2 = ALO2 + O ,          A=  1.0E11 , N= -0.5 , B=  6.652 , ESTIMATE
ALO + HO2 = ALO2 + OH ,        A=  1.0E11 , N= -0.5 , B=  3.6025, ESTIMATE
ALO2 + H2 = H + ALO2H ,        A=  1.0E11 , N= -0.5 , B=  5.731 , ESTIMATE
ALO2 + OH = O + ALO2H ,        A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALO2 + HCL = CL + ALO2H ,      A=  1.0E11 , N= -0.5 , B=  5.6765, ESTIMATE
ALOH + O2 = O + ALO2H          A=  1.0E11 , N= -0.5 , B=  6.556 , ESTIMATE
ALOH + OH = H + ALO2H ,        A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALOH + CLO = CL + ALO2H ,      A=  1.0E11 , N= -0.5 , B=  3.6365, ESTIMATE
AL + H2O = ALOH + H ,          A=  1.0E11 , N= -0.5 , B=  7.0015, ESTIMATE
ALO + H2 = ALOH + H ,          A=  1.0E11 , N= -0.5 , B=  5.731 , ESTIMATE
ALO + HCL = ALOH + CL ,        A=  1.0E11 , N= -0.5 , B=  5.6705, ESTIMATE
ALO + OH = ALOH + O ,          A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALH + H = AL + H2 ,            A=  5.0E11 , N= -0.5 , B=  3.76  , ESTIMATE
ALH + OH = AL + H2O ,          A=  5.0E11 , N= -0.5 , B=  3.76,   ESTIMATE
ALH + O = AL + OH ,            A=  5.0E11 , N= -0.5 , B=  3.76,   ESTIMATE
ALH + CL = AL + HCL ,          A=  5.0E11 , N= -0.5 , B=  3.76,   ESTIMATE
 AL + ALCL2=ALCL + ALCL , A=5.E11,N=-0.5,B=6.1500,            ESTIMATE
```

The symbolic reaction set contains directive cards and reaction/data cards in groups as outlined below:

REACTIØNS	Directive for start of symbolic reaction input
.	
.	Reactions with implied third body species
END TBR REAX	Directive for end of third body reactions
.	
.	All other reactions
.	
LAST REAX	Directive for end of reactions
INERTS	Specified inert species
THIRD BØDY REAX RATE RATIØS	Directive for start of third body reaction rate ratios
.	
.	Third body reaction rate ratios
.	
LAST CARD	Directive for end of REACTIØNS input

The content and format of each type of card is defined as follows:

2.8.2.1 The symbolic reaction set begins with a card containing the word REACTIØNS in columns 1 through 9. Other columns on this card can be used for comments.

2.8.2.2 Each card defining a reaction is divided into five fields, separated by commas. Each field contains:

field 1	a reaction	
field 2	A = followed by a value of A	rate parameters for the reactions
field 3	N = followed by the value of N	
field 4	B = followed by the value of B, the activation energy (Kcal/mole)	
field 5	available for comments	

The general form of a reaction is:

$$N_1 *Symbol_1 + N_2 *Symbol_2 + \dots = N_a *Symbol_a + N_b *Symbol_b + \dots$$

where the left hand side represents reactants and the right hand side represents products. The reaction can be either endothermic or exothermic.

The multipliers, N, must be integers and represent stoichiometric coefficients. If no stoichiometric coefficient is given, the value 1 is assumed. The dimensioning currently in the program requires that:

$$N_1 + N_2 + \ldots \leq 10$$

and

$$N_a + N_b + \ldots \leq 10$$

The chemical species (denoted by the word "symbol" in the above general form) can contain up to 12 characters, each of which must match a species name contained in the thermodynamic data (see Table 2-2, card 3). Examples:

Reaction	Interpretation
NA++CL-=NACL	$Na^{+} + Cl^{-} = NaCl$
B+2+Ø-2=BØ	$B^{++} + Ø^{--} = BØ$
BE+2+2*ØH-=BEØHØH	$Be^{++} + 2ØH^{-} = Be(ØH)_2$

The value assigned to A, N, B defines the forward (i.e. left to right) reaction rate, k, as

$$k = A \cdot T^{-N} \cdot e^{-(1000B/RT)}$$

in units of cc, ^{o}K, mole, sec.

All three reaction rate parameters must be input. The numeric value of each parameter may be specified in either I, F, or E format. If E format is used, the E must appear before the exponent.

2.8.2.3 The reactions with an implied third body must precede other types of reactions, and must be followed by the directive (columns 1 through 12):

```
Col 1 ↓
      END TBR REAX
```

all reactions prior to the above directive will have a third body term added to each side of the reaction, e.g.,

H2 = H + H, ...

END TBR REAX

defines the chemical reaction

$$H_2 + M = H + H + M$$

where M is a generalized third body. Specific third body effects may be included by inputing specific third body reaction rate ratios as outlined in 2.8.4. Cards encountered after the END TBR REAX directive card do not have a third body term added.

2.8.2.4 All other reactions are input next, exactly as described under 2.8.2.2.

2.8.2.5 After the last reaction has been defined, a card with LAST REAX in columns 1 through 9 is input.

2.8.2.6 Reaction rate data for 14 dissociation-recombination (implied third body) reactions and 59 binary exchange reactions are listed in Table 2-13 for propulsion systems containing elements C, N, O, H, Cl and Al. Cards can be abstracted from Table 2-13 for input to the computer program. For the implied third body reactions, the third body for which the rate applies is indicated in parenthesis in the comment field (M represents a "generalized" third body).

2.8.3 <u>INERT SPECIES OPTION</u>

Inert species (i.e. species not appearing in reactions) can be included in the input by input of a card with INERTS in columns 1 through 6 followed by a list of inert species names. The species names must each be followed by a comma and each name must be written exactly as in the master thermodynamic data. The last comma must be followed by the word END. See Table 2-14 for an example. The species list can continue on to the next card, but a species name cannot overlap onto the next card.

2.8.4 THIRD BODY REACTION RATE RATIOS

As described above in Section 2.8.2.2 for the j^{th} reaction only one reaction rate, k_j, where

$$k_j = AT^{-N_j} e^{-B_j/\Re T}$$

can be input. For three body recombination reactions such as

$$H + \text{ØH} + M_i = H_2\text{Ø} + M_i$$

the rate of reaction is in general different for each species, M_i, depending upon the efficiency of the species, M_i, as a third body collision partner. The temperature dependence of a recombination rate is approximately independent of the third body; i.e., for the i^{th} third body and j^{th} reaction:

$$k_{ij} \doteq A_{ij} T^{-N_j} e^{-B_j/\Re T} \quad .$$

The third body efficiency of the i^{th} species for the j^{th} reaction is then defined as

$$m_{ij} \equiv A_{ij}/A_j \quad .$$

Thus m_{ij} is the ratio of the reaction rate with species M_i as the third body to the reaction rate input on the reaction card described in Section 2.8.2.2.

If reaction rate ratios, m_{ij}, are to be input for the dissociation-recombination reactions, a card with THIRD BØDY REAX RATE RATIØS in columns 1 through 27 must be input next. <u>If this card is deleted from the input, the program assumes all $m_{ij} = 1$.</u> If this card is included in the input, it must be followed either by a card with ALL EQUAL 1.0 in columns 1 through 13 (which sets all $m_{ij} = 1$) or by SPECIES cards as described below.

The m_{ij} can be input using a card with the word SPECIES in columns 1 through 7. This word is followed by the <u>name of the i^{th} species</u> followed by a comma, followed by the values m_{ij} in F format, each followed by a comma. These m_{ij} values can be continued onto succeeding cards. Note that the m_{ij}

TABLE 2-14 LISTING OF SAMPLE REACTIONS CARDS FOR AN O_2/H_2 PROPELLANT

```
REACTIONS    O-H        MAY 3-4 1972  JANNAF PSWG
   H + OH  = H2O         , A=7.5E23 , N=2.6 , B=0.,                      (AR) NO.
   O + H   = OH          , A=4.0E18 , N=1.  , B=0.,                      (AR) NO.
   O + O   = O2          , A=1.2E17 , N=1.  , B=0.,                      (AR) NO.
   H + H   = H2          , A=6.4E17 , N=1.  , B=0.,                      (AR) NO.
END TBR REAX
  H2 + OH  = H + H2O     , A=2.19E13, N=0.  , B=5.15,                   BAULCH  NO. 2
  OH + OH  = O + H2O     , A=5.75E12, N=0.  , B=.780,                   BAULCH  NO. 2
   H + OH  = O + H2      , A=7.33E12, N=0.  , B=7.300,                  BAULCH  NO. 2
   O + OH  = H + O2      , A=1.3E13 , N=0.  , B=0.,                     BAULCH  NO. 2
LAST REAX
INERTS N2,AR,END
THIRD BODY REAX RATE RATIOS
SPECIES AR,1.,1.,1.,1.,
SPECIES H2,5.,5.,5.,4.,
SPECIES H2O,20.,5.,5.,20.,
SPECIES O2,5.,5.,4.5,1.5,
SPECIES N2,4.,4.,4.,1.5,
SPECIES H,12.5,12.5,12.5,25.,
SPECIES O,12.5,12.5,12.5,25.,
SPECIES OH,12.5,12.5,12.5,25.,
LAST CARD
```

values depend on the order of input of the reaction cards, i.e. the j^{th} reaction is defined by the j^{th} card input after the REACTIØNS card.

Table 2-11 gives a sample input for a hydrogen/oxygen system using third body reaction rate ratios. In this example the three body recombination rates are input with argon as the third body. The rate with H_2 as a third body is a factor of five larger than with Ar as a third body for the first three reactions and a factor of four larger for the fourth (hydrogen recombination) reaction.

At this point in the data input deck, a card with LAST CARD in columns 1 through 9 must be input.

2.8.5 $ØDK NAMELIST INPUT

$ØDK Namelist input specifies the conditions for the kinetic expansion calculation. The input is read in subroutine ØDKINP and consists of the following groups of data as outlined below:

2.8.5.1 Inlet, Throat, and Expansion Nozzle Geometry
2.8.5.2 Integration Control
2.8.5.3 Print Control
2.8.5.4 Species Selection and Mass/Mole Fraction Check
2.8.5.5 ØDK Problem Input

2.8.5.1 INLET, THROAT, AND EXPANSION NOZZLE GEOMETRY

The nozzle geometry is defined in Figure 2-2. At the tangent point where the nozzle is attached to the throat section either a cone, parabola, circular arc, nozzle defined by a wall table may be input. Two radii of curvature for the throat wall (upstream and downstream) are allowed in ODK (TD2P allows only a single radius of curvature).

Certain of the $ØDK Namelist items are communicated from the $GEØM Namelist data set. These items will be prefixed with a plus (+) sign. Input of any of these data items in the $ØDK Namelist set will override the values input in the $GEØM Namelist in this calculation module only.

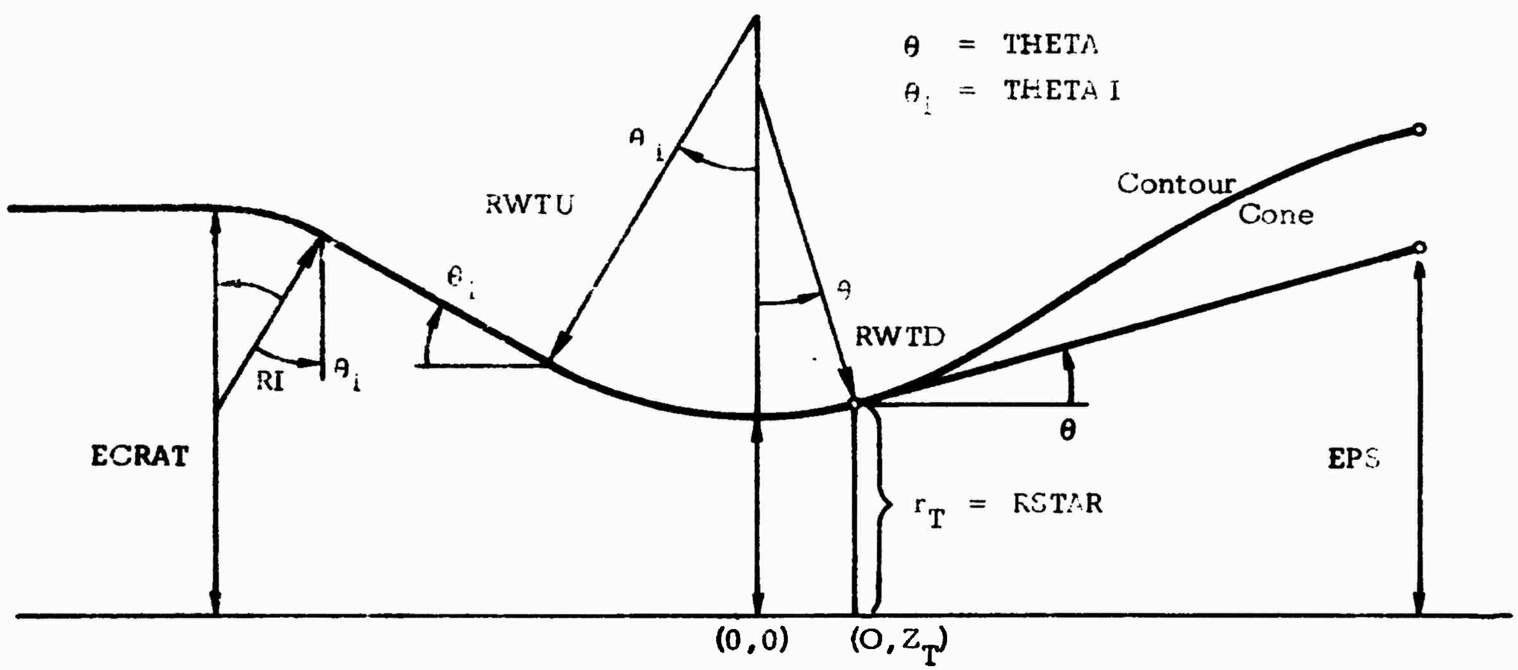


Figure 2-2 ODK Nozzle Geometry

Item Name		Input Quantity	Units	SI Units
+RSTAR	=	throat radius	inches	meters
+RWTU	=	upstream normalized wall throat radius of curvature*	none	none
+RWTD	=	downstream normalized wall throat radius of curvature**	none	none
+THETAI	=	inlet angle	degrees	degrees
+RI	=	normalized inlet wall radius of curvature	none	none

For a Conical Nozzle Option

Item Name		Input Quantity	Units
+IWALL	= 1	requests cone option	none
+THETA	=	cone angle	degrees
+EP	=	nozzle expansion ratio (≤400). If EP is input, the ØDK expansion will be through EP.	
EPS	=	set equal to EP	none

Note: Parabola (IWALL=2) and circular arc (IWALL=3) options are available only through use of the $GEOM Namelist.

*The transonic analysis requires that a value of RWTU ≥ .5 be input. RWTU = RWTD if data comes from $GEØM.

**If a corner expansion (i.e. Prandtl-Meyer fan) is desired, a value of RWTD = .05 is recommended. Experience has shown that values smaller than this give the same result but are computationally less efficient.

For a Contoured Nozzle Option

Item Name		Input Quantity	Units
+IWALL	= 4	requests contour option	none
+THETA	=	wall angle at tangent point	degrees
+THE	=	wall angle at exit	degrees
+NRZS	=	number of points in table, ≤20	none
+PWRS(2)	=	normalized radial wall coordinate table*	none
+PWZS(2)	=	normalized axial wall coordinate table*	none
RZNØRM	=	optional normalization factor for input wall coordinate tables	none

2.8.5.2 INTEGRATION CONTROL

The program begins its calculations using an implicit integration method to integrate the fluid dynamic and chemical relaxation equations. For near equilibrium flow an implicit method is used since it is inherently stable. However, once the flow has become sufficient frozen, explicit methods become numerically stable and can be used more efficiencly. The program uses temperature as a freeze criterion in order to switch from an implicit to an explicit method. This criterion is T < TEXPLI where TEXPLI is assumed $0^{o}R$ but may be input. The program always prints the axial position at which the switch occurs. For high area ratio nozzles this procedure can be especially useful.

The integration routine controls the step size such that the relative error in the dependent variable increments are less than a prescribed fraction, DEL. Only doubling or halving of the step size is permitted, and on option, either all the variables may be considered (JF=0), or only the fluid dynamic variables (JF=1) may be considered.

*PWRS(1) and PWZS(1) are internally computed at the coordinates of the contour attachment point.

When the flow becomes supersonic and the area defined fluid dynamic equations are used, an additional check on continuity is applied in the form

$$\left| \frac{(\rho VA)_{N+1} - (\rho VA)_N}{(\rho VA)_{N+1}} \right| < \text{CØNDEL}$$

where CØNDEL is an input relative criterion.

The step size is held between the two input bounds HMIN and HMAX. Fixed step cases may be run by setting input values for HI, HMAX, HMIN all equal.

Item Name		Input Quantity	Units	Assumed Value(s)
HI	=	initial step size	none	.01
HMAX	=	upper bound on step size	none	0.10001
HMIN	=	lower bound on step size	none	.005
DEL	=	fractional incremental error	none	.001
TEXPLI	=	temperature below which explicit integration will start	°R	-
CØNDEL	=	relative error criterion for continuity check for super-sonic flow	none	1×10^{-6}
JF	= 0	all variables considered for step size control	none	0
	= 1	only fluid dynamic variables considered for step size control	none	

2.8.5.3 PRINT CONTROL

Output from the Kinetic Expansion Calculation consists of complete output for each print station selected. The end point of the nozzle is always printed. Print stations are selected from one of the following options:

Item Name		Function	Assumed Value(s)
JPRNT	= -2	print throat and input area ratios	-1
	= -1	print at internally set area ratios for conical nozzle.* Print at input wall contour points for contoured nozzles	
	= 0	print at every integration step	
	= +1	print every ND3rd step up to the throat and then nominal area ratios	
	= +2	print every ND3rd step over entire nozzle	

If JPRNT is +1 or +2, the following must be input:

Item Name		Function	
ND1	=	first integration step to be selected for print	-
ND2	=	last integration step to be selected for print	-
ND3	=	print every ND3rd step between ND1 and ND2.	-

If JPRNT is -2, the following must be input:

Item Name		Function	
+ARPRNT(1)	=	requested area ratios for print, must be monotonic increasing and greater than 1.0 (usually entries are the same as those used in SUPAR of $ØDE).	-
+NJPRNT	=	number of area ratios requested for print ≤ 100.	-

An extended print option may be selected as follows:

Item Name	Value	Function	
IDYSCI	= 0	no extended print requested	0
	= 1	extended print option selected (not suggested)	

*For JPRNT = -1 and a conical nozzle (i.e. IWALL = 1), the internally set area ratios are:
ARPRNT(1) = 2,3,4,...,39,40,42,...,58,60,64,...116,120,128,...,200,210, 220,...,400,412,444.

2.8.5.4 SPECIES SELECTION AND MOLE/MASS FRACTION CHECK

In order to interface ØDE equilibrium calculated start conditions with a the kinetic expansion calculations, special consideration must be made for inert species (those not appearing in the reaction set). Inerts may be selected explicitly by use of the INERTS directive or by use of a relative selection criterion. The INERTS directive is described in Section 2.8.2.5.

The relative selection criterion is described below:

Item Name		Function
EPSEL	=	all species which do not appear explicitly in the reaction set but whose mole fractions are greater than the input value for EPSEL, will be retained for the kinetic expansion. Species selected under this criterion are treated as inert. The program assumes EPSEL = 1.0E-5, unless input.

In some instances it may be desirable to use input species concentrations which do not sum to unity. Species concentrations, either input or from equilibrium start conditions, are summed and the sum checked as described below:

Item Name		Function
XMFTST	=	input species concentrations are summed and checked versus unity using this input criterion. If $\left\| 1 - \sum \text{species concentrations} \right\| < \text{XMFTST}$ then the test is passed. The species concentrations will then be normalized such that $\sum$ species concentrations = 1.

The program assumes XMFTST = 1.0E-3, unless input.

If the test is not passed, an error message will be given and the run terminated.

2.8.5.5 ØDK PROBLEM INPUT

This input is required when an ØDK calculation is requested without restricted equilibrium start conditions being requested. A kinetic expansion from input arbitrary start conditions is to be computed. In addition to the input items described in Section 2.8.5, an ØDK problem requires input of those items described in Sections 2.8.1 and 2.8.2.

Item Name		Input Quantity	Units
PC	=	chamber pressure	PSIA
T	=	initial temperature	^{o}R
V	=	initial gas velocity	ft/sec
JPFLAG	= 0	pressure table calculated internally	none
	= 1	pressure table input	none
ECRAT	=	initial contraction ratio	none

For JPFLAG = 0 option, the following must be input:

Item Name		Input Quantity	Units
PI	=	initial pressure	PSIA
PESTAR	=	throat pressure	PSIA

For JPFLAG = 1 option, the following must be input:

Item Name		Input Quantity	Units
PTB(1)	=	normalized pressure table entries*	none
ZTB(1)	=	normalized pressure table coordinates**	none
NTB	=	number of pressure table entries, ≤127	none
Z	=	initial axial position	none

*normalized to input chamber pressure, PC
**normalized to input throat radius, RSTAR

2.9 Two-Dimensional-Two Phase Flow (TD2P) Module Input

Data required to execute the TD2P module is read in under the namelist name $TD2. Certain of the input items described below are either communicated to the TD2P module by the GEØM, BAL, and/or ØDE modules or are preset in the TD2P module. Hence, these data items do not necessarily need to be input in the $TD2 namelist set. However, any values that are input will override the communicated or preset values.

The input data items to the TD2P module are as follows:

Item		Description	Units	Assumed Value(s)
$TD2		namelist name		
		The following items are communicated from the ØDE or BAL module if ØDE or BAL=1. or 2. has been input in the $PRØB namelist.		
PR	=	Prandtl Number	none	0.0
GMGØ	=	chamber gas viscosity coefficient	lbm/ft.sec.	-
CAPN	=	viscosity temperature exponent	none	-
CPL	=	liquid particle heat capacity ($T_p > T_{p_m}$)	ft²/sec² °R	-
TPM	=	T_{p_m}, particle solidification temperature	°R	-
DHM	=	latent heat of melting for the particles	ft²/sec²	-
EPM	=	expansion ratio at which solidification of the particles begins in an ØDE type calculation	none	-
UGM	=	gas velocity at the ØDE solidification point	ft/sec	-
TPS	=	gas temperature at some point after solidification has been completed.	°R	-
UGS	=	gas velocity corresponding to the value of TPS	ft/sec	-
PC	=	chamber pressure	psia	-
TGO	=	chamber temperature	°R	-
WPWGT	=	ratio of particle to gas weight flow	none	-
XMLW	=	molecular weight of the condensed phase	lb/lb-mole	101.96

On the following geometric input data, the items preceded by an asterix (*) will have been communicated by the GEØM or BAL module if they were input in the $GEØM namelist set or calculated by the ballistics (BAL) module.

Inlet and Throat Parameters (see Figure 2-3)

Item		Description	Units	Assumed Value(s)
DZI	=	Δz, particle trajectory integration step size	none	.002
DZMIN	=	Δz_{min}, inlet step size parameter	none	.002
NILP	=	N_i, number of initial line points	none	20
*RRT	=	R_c, throat radius of curvature. A value $R_c > 1$ is required	none	-
*RT	=	r^*, throat radius	ft	-
SAUR(1)	=	first estimates of x_o, u_o, α, β, and γ for the special throat expansion. Required only if $\theta_i > \theta_f$	none	-.15,1,.5, .3,-1
THFD	=	θ_f, faring angle ($\theta_f > \theta_i$ = > no faring)	degrees	5.
*THID	=	θ_i, inlet angle	degrees	
THIW	=	θ_{i_w}, intersection of initial line and wall	degrees	12.
THJD	=	θ_j, angle defining the zone farthest downstream	degrees	9.
VAR(1)	=	first estimates of x_o, u_o, α, β, and γ for the zone farthest upstream	none	.3,0,0, .1,.1
ZAX	=	z_{axis}, intersection of initial line and axis	none	-
ZI	=	n_i, number of upstream zones	none	3.
ZJ	=	n_j, number of downstream zones	none	2.
NTBL	=	number of points in the subsonic-transonic region to be output for input to the TBL module	none	15
XITBL	=	starting normalized axial position for the output to TBL	none	-
*XLSTAR	=	motor L*, if input in $GEØM, it will be used unless it is calculated in the Ballistics module. In which case, the average L* from the ballistics module will be used. A value input here will over-ride previous values.	in	-

Characteristics Mesh Control Data

DL	=	$\Delta \ell$, maximum LRC mesh width	none	.2
DTWI	=	$\Delta\theta_w$, maximum flow angle change along the wall	degrees	3.
DR	=	Δr, maximum RRC mesh width	none	.2

Variable	Input Name
r_i	RRT
r^*	RT
θ_f	THFD
θ_i	THID
θ_{i_w}	THIW
θ_j	ThJD
Z_{axis}	ZAX
θ_j	THJW

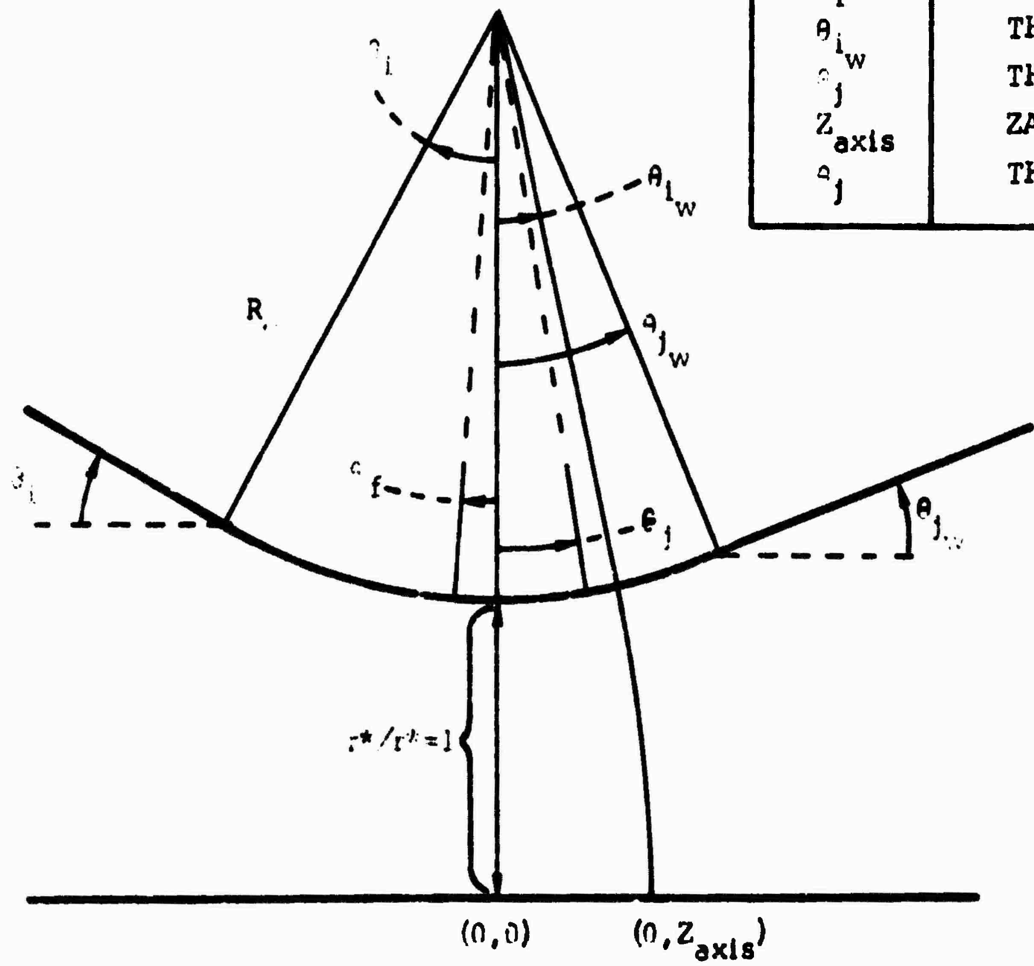


Figure 2.3. Inlet and Throat Parameters

Item		Description	Units	Assumed Value(s)
EW	=	ϵ_w, end of nozzle wall criterion	none	.001
IMAX	=	i_{max}, maximum number of iterations per mesh point	none	5
N1	=	n_1, select each n_1^{th} LRC for print	none	1000
N2	=	n_2, print each n_2^{th} point on selected	none	1
		Nozzle Wall Contour Data		
*IWALL	=	Option flag 0 = >tabular input (not allowed in $GEØM) 1 = >cone 2 = >parabola 3 = >circular arc 4 = >wall contour (spline) option	none	-
		If the wall is to be input in tabular form (IWALL=0):		
PW(I)	=	(r_i, z_i), wall coordinates $i = 1,2, \ldots, n$ points, viz.: $PW(I) = r_1, z_1, r_2, z_2, \ldots, r_n, z_n, 0,0$ Note: a) always mark the end of the table with two zeros b) $n \leq 74$ is required c) always set r_1=1+RRT(1-cos THIW) and z_1=RRT sin THIW	none	-
*EPS	=	ε, nozzle expansion ratio	none	-
		If a cone, parabola, or circular arc contour is to be specified then:		
*THJW	=	θ_{j_w}, attachment angle for the contour; e.g. for a cone, the conical half angle	degrees	-
*EPS	=	ϵ, nozzle expansion ratio (cone only).	none	-
*RWMAX	=	r_{max}, nozzle exit radius (parabola or arc only).	none	-
*ZWMAX	=	z_{max}, nozzle length from throat to exit (parabola or arc only).	none	-

Item		Description	Units	Assumed Value(s)
		For a Contoured Nozzle		
*THE	=	wall angle at exit	degrees	
*NRZS	=	number of points in table, ≤ 20	none	
*PWRS(2)	=	normalized radial wall coordinate table+	none	
*PWZS(2)	=	normalized axial wall coordinate table+	none	
		Particle Data		
ITØT	=	number of particle groups to be considered	none	5
SMP	=	particle density	lbm/ft^3	250.
R(1)	=	r_{p_j}, the radius of each of n particles is to be input so that $r_{p_1} < r_{p_2} \ldots < r_{p_n}$ set $r_{p_{n+1}} = 0$. $n < 10$ is required.	ft	0.0
WPWT(1)	=	$\dot{w}_{p_j} / \Sigma \dot{w}_{p_j}$, particle weight flow fractions corresponding to each of the above particle radii, r_{p_j}	none	

Note: The mean particle diameter and distribution will be calculated from the following data if R(1) = 0.0. The equation

$$d_p = XK \cdot PC^{PEXP} \cdot (\xi)^{XIEXP} \; (1-EXP(XL*XLSTAR)) \; *(1+24 \cdot XD \cdot r^*)$$

is used to calculate the mean particle diameter in microns.

XK	=	constant in the d_p calculation	$\frac{\text{microns}}{PSI^{PEXP}}$	0.454
PEXP	=	constant in the d_p calculation	none	.33334
XL	=	constant in the d_p calculation	in^{-1}	-.004
XD	=	constant in the d_p calculation	in^{-1}	.045
XIEXP	=	constant in the d_p calculation	none	.33334

In the above formula: ξ is the concentration of condensed phase (moles/100 gr products) calculated from WPWGT and, PC is in psia, r* is the throat radius in feet.

SIG	=	geometric standard deviation used in the particle size distribution	none	1.9
$END		end of $TD2 namelist set		

+PWRS(1) and PWZS(1) are internally computed at the coordinates of the contour attachment point.

2.10 Turbulent Boundary Layer Module Input

Data required to execute the Turbulent Boundary Layer (TBL) Module is read in under the namelist name $TBL. Certain of the input items described below are either communicated to the TBL module by the ØDE and/or TD2P modules or are preset in the TBL module. Hence these data items do not necessarily need to be input to the TBL module. However, any value that is read in will override the assumed or communicated value.

The input data items to the TBL module are as follows.

Item		Description	Units	Assumed Value(s)
$TBL		namelist name		
		The following items are communicated from the ØDE module if ØDE = 1 or 2.		
T0	=	Stagnation temperature (from ØDE-chamber temperature)	°R*	-
P0	=	Stagnation pressure (from ØDE-chamber pressure)	psf*	-
PR	=	Prandtl number	none	-
ZMU0	=	Value of viscosity, μ, at the stagnation temperature	lbm/ft-sec.*	-
ZMVIS	=	Exponent in the viscosity-temperature equation $\mu = ZMU0*(T/T0)^{ZMVIS}$	none	-
		The following items are communicated from the TD2P module if TD2P = 1 or 2.		
P0	=	Stagnation pressure (from TD2P-the value of stagnation pressure at the initial line)	psf*	-
GAM0	=	Stagnation value of specific heat ratio	none	-
RBAR	=	Value of gas constant	ft^2/sec^2 °R*	-
IXTAB	=	Number of points in the x, y and Mach number tables	none	-
SCALE	=	If it is desired, non-dimensional values of x and y may be input and then multiplied by a single scale factor. (from TD2P, SCALE=r*)	FT*	1.0
T0	=	Stagnation temperature (from TD2P the value of the stagnation temperature at the initial line).	°R*	-

Item		Description	Units	Assumed Value(s)
WDØT	=	Mass flow rate	lbm/sec	-
XITAB(1)	=	IXTAB values of x, axial distance, in monotonically increasing order (from TD2P-XITAB(I)=x_i/r^*)	none*	-
YITAB(1)	=	IXTAB values of y, nozzle radius or contour height in consecutive order corresponding to each x of XITAB. (from TD2P-YITAB(I)=r_i/r^*)	none*	-
ZMTAB(1)	=	IXTAB values of free stream Mach number in consecutive order corresponding to the contour points x_i, y_i	none	-

The following items are preset or must be input to the TBL module.

Item		Description	Units	Assumed Value(s)
MZETA	=	Velocity power law exponent, n	none	7
IPRINT	=	0 Prints only at input intervals 1 Prints at all calculated points	none	0
ICTAB	=	0 Indicates a constant specific heat calculation = ≥ 3 Number of points in C_p versus T table	none	0
ITWTAB	=	-1 T_w = adiabatic wall temperature 0 T_w = constant (see TWTAB) 1 IXTAB values of T_w will be input (see TWTAB)	none	-1
ZNSTAN	=	Interaction exponent n, in Stanton number relation	none	.1
DXMAX	=	Maximum length of step size. If DXMAX is not input DXMAX is computed to be 1/100 the length of the contour	ft*	.01x
EPSZ	=	Geometry indicator 0. Two-dimensional Planar flow 1.0 Axisymmetric flow	none	1.0
FJ	=	Conversion factor between thermal and and work units	$\frac{\text{ft-lbf*}}{\text{BTU}}$	778.2
G		Proportionality constant in equation F=(m/g)a	$\frac{\text{ft-lbm*}}{\text{sec}^2\ \text{lbf}}$	32.174
TCTAB(1)	=	ICTAB values of temperature in increasing order, defining the C_p-T table. The maximum T should exceed T_o and the minimum T should be below the lowest temperature likely to be encountered in the system	°R*	

Item		Description	Units	Assumed Value(s)
+CPTAB(1)	=	ICTAB values of C_p in consecutive order corresponding to the values in the temperature table.	BTU*/ lbm °R	-
TWTAB(1)	=	If ITWTAB = -1 omit this input If ITWTAB = 0 input one value of wall temperature If ITWTAB = 1 input IXTAB values of wall temperature corresponding to the wall locations of the x and y tables	°R	-
TØLCFA	=	Tolerance in $C_f - C_f R_\theta$ interaction loop	none	.0001
TØLZET	=	Tolerance in zeta interaction loop	none	.0003
TØLZME	=	Tolerance used in gas property evaluation loops	none	10^{-7}
THETAI	=	Initial value of momentum thickness. If THETAI is input as a negative value, the sonic point start procedure will be actuated.		-
PHII	=	Initial value of energy thickness. This need not be input if the sonic point start procedure is used		-
		Edge condition option flag		
IFEDGE	=	0 edge conditions are computed from the Mach number table	none	0
	=	1 tables of P_e/P_c, T_e/T_c, C_{p_e}, V_e, ρ_e are to be input as below		
		≥ 2 tables of P_e, T_e, C_{p_e}, V_e, ρ_e are to be input as below		
PITAB(1)	=	IXTAB values of P_e/P_c or P_e versus X (see IFEDGE)		-
TITAB(1)	=	IXTAB values of T_e/T_c or T_e versus X(see IFEDGE)		-
+CPITAB(1)	=	IXTAB values of C_{p_e} versus X	BTU/lbm* °R	-
VITAB(1)	=	IXTAB values of V_e versus X	ft/sec*	-
RØITAB(1)	=	IXTAB values of ρ_e versus X	lbm/ft^3*	-
$END				

*NOTE-Any consistant set of units in accordance with the values of FJ and G may be used. The units shown are those consistant with the values communicated from the ØDE and TD2P modules and by the TBL module back to the SPP control routines.

+NOTE-If a C_p table is not input into the program (see CPTAB and ICTAB), the program will attempt to edit in a C_p table from the values of C_{p_e} vs. T_e. However, the edited values may not (especially in the cold wall case) cover the entire range of values required for the run. The safest procedure is to generate by hand a CPTAB table which includes several values of C_p for both the upper and lower temperature extremes.

2.11 Linkage

The linkage between the five basic computational modules in the SPP computer program was designed to give the user of the code flexibility in selecting which of the modules need be used in any one computer run. While all of the modules may be used in any one computer run, this is not usually the most efficient approach, since input mistakes or the use of the program in parametric studies could require the repeated successful execution of several of the modules. Thus, for the sake of efficiency, and overall flexibility, all of the linkage data between modules (except for the restricted equilibrium interface between the ØDE and ØDK modules) is written out on logical unit 8 as formated data. This data may then be manipulated in a number of fashions depending on the computer hardware and utility routines which are available. On 6000 series CDC equipment which the program was developed for, logical unit 8 was equivalenced to the formated punch file. Hence, at the completion of a run, the linkage data would be punched out and made available for subsequent runs (described below), eliminating the need for repeating an already successful solution.

This type of linkage has two major advantages. The first is obviously a savings in computer run time on series of cases wherein the output from one or more modules is unchanged. The second is the ability to use other analyses (if appropriate) to "fool" the SPP code into accepting them as an integral part of its own computational procedure. This second approach allows the engineering user the flexibility to substitute the output from any other code or analysis into the procedure defined in the SPP code as long as it conforms to the proper format.

Data is read in on subsequent runs by the SPP program on logical unit 3 if the calculation module equals 2 option is selected in the SPRØB namelist. However, this logical unit may be changed to any value by input in the SPRØB namelist. This feature allows the punched output linkage data to be read in as part of the normal card input stream as long as the linkage data is in the following order:

```
$PRØB
module option = 2,
$END
 ØDE    data*
 BAL    data*
 ØDK    data*
 TD2P   data*
 TBL    data*
 the rest of the input data
```

*this data is only needed if the module option =2 is selected in the $PRØB namelist.

The data does not need to conform to the above order as long as the data resides on logical unit 3 or any other logical unit which is not assumed to be the card input stream.

Certain complications can arise when previously calculated (punched) data is used out of the ordinary calculation sequence presented in Table 2-1 of Volume III or Figure 2-2 of Volume II. For example, if the ØDE module is executed while the ballistics module (BAL) data is read in from cards, the chamber pressure from the ØDE module is used in the TD2P module instead of the average pressure calculated by the BAL calculation. While nominally small, the difference between these two pressures can cause slight differences in the performance results calculated by these modules. In any event, this deficiency will be corrected in any further versions of the SPP code.

The punched (or formated output) from each of the computational modules conforms to the same basic format. The first card image contains the name of the module,while the last image contains the word END. The data between these cards consists of sequenced "packets" of information which contain the linkage data. A packet may consist of one or more data cards, all of which have the same sequence number. Table 2-15 contains the basic format used in generating the linkage data. Tables 2-16 through 2-20 describe the specific data transmitted between modules.

Table 2-15 Basic Format of Linkage Data

Card	Format	Description
first	A4	name of module
all others	5X, 5E14.6, I5	data and packet sequence number
last	A3	the word END

Note that in the following five (5) tables the first and last cards have been omitted and that the five fields refered to are the five floating point data fields described in Table 2-15.

Table 2-16 ØDE Linkage Data

"Packet"	Field	Description
1	1	μ_{ref} - reference viscosity - lbm/ft. sec.
	2	ω - viscosity exponent in $\mu = \mu_{ref} (T/T_c)^{\omega}$
	3	T_c - chamber temperature - °R
	4	P_c - chamber pressure - atm.
	5	μ_c - chamber viscosity - lbf · sec/ft²
2	1	κ_c - chamber gas thermal conductivity - lbf/sec-°R
	2	γ_{eq} - chamber equilibrium ratio of specific heats
	3	β - erosion parameter
	4	c^*_{th} - theoretical $c^* = P_c A^*/\dot{m}$ - ft/sec
	5	c_{p_c} - chamber equilibrium specific heat - BTU/lbm °R
3*	1	ϵ_{melt} - area ratio at solidification
	2	u_{melt} - velocity at solidification - ft/sec
	3	T_{melt} - temperature at solidification - °R
	4	α - fraction of condensed phase to gas phase
	5	ΔH_{melt} - heat of melting of condensed phase (ft²/sec²/lbm)
4*	1	c_{p_ℓ} - specific heat of the liquid - (ft²/sec²)/lbm °R
	2	c_{p_s} - specific heat of the solid - (ft²/sec²)/lbm °R
	3	$M_{w_{cp}}$ - molecular weight of the condensed phase
	4	T_{exit} - temperature at the exit plane - °R
	5	U_{exit} - velocity at the exit plane - ft/sec
5	1	$M_{w_{gas}}$ - molecular weight of the gas only
	2	$M_{w_{mix}}$ - molecular weight of the mix
	3	$M_{w_{eff}}$ - effective molecular weight of the mixture
	4	Pr_c - chamber Prandtl number
	5	$I_{sp_{th}}$ - theoretical I_{sp} at the exit plane
6	1	I_{sp_f} - frozen I_{sp} at the exit plane

*Not used if no condensed phase is present.

Table 2-17 Ballistics Linkage Data

Packet	Card in "Packet"	Field	Description
all			
	1	1	t - time - sec
		2	P_c - chamber pressure - PSIA
		3	P_{max} - maximum pressure to this time - PSIA
		4	R* - throat radius - in
		5	L* - motor L* - in
	2	1	η_c^* - fractional c* efficiency
		2	$\dot{m}$ - mass flux - slugs/sec
		3	$\dot{m}_i/\dot{m}_p$ - ratio of insulation to propellant mass flow
		4*	P_{ci} - head end chamber pressure - PSIA
		5	$\int \dot{m}dt$ - mass expended to this time - slugs
	3	1*	F - thrust - lbf

* not currently used

Table 2-18 ØDK Linkage Data

Packet	Field	Description
1→N*	1	ϵ_{RE} - area ratio corresponding to I_{sp} in field 2
	2	$I_{sp_{RE}}$ - "Restricted" equilibrium I_{sp}
	3	ϵ_{RE} - area ratio corresponding to I_{sp} in field 4
	4	$I_{sp_{re}}$ - "Restricted" equilibrium I_{sp}
N+1→END	1	ϵ_K - area ratio corresponding to I_{sp} in field 2
	2	I_{sp_k} - "kinetic" I_{sp} as calculated by ØDK

*The packets 1→N are terminated by a negative number in field 3 (if the number of restricted equilibrium points is odd) or, by the start of the ØDK data (if the number of restricted equilibrium points is even). If no restricted equilibrium points are available, the kinetic efficiency will be calculated as $\eta_{KIN}=1.C$. The restricted equilibrium pairs need not be in order as this table is sorted.

Table 2-19 TD2P Linkage Data

"Packet"	Field	Description
1	1	C_D - discharge coefficient
	2	R - gas constant, $ft^2/sec^2/°R$
	3	γ - specific heat ratio as calculated by TD2P
	4	C_p - specific heat, $ft^2/sec^2/°R$
	5	$\dot{m}$ - mass flux, lbm/sec (for single nozzle in multiple nozzle cases)
2	1	P_o - stagnation pressure at the TD2P wall initial point, psi
	2	T_o - stagnation temperature at the TD2P wall initial line point, °R
3→END	1	r_i/r^* - normalized nozzle wall radius
	2	z_i/r^* - normalized axial distance
	3	M_i - Mach number on wall streamline
	4	$I_{sp_{TD2P_i}}$
	5	η'_{TD2P_i}

Table 2-20 TBL Linkage Data

Packet	Field	Description
all	1*	r - wall radius - ft
	2	ΔI_{sp} - I_{sp} decrement due to turbulent boundary layer

An axisymmetric nozzle has been assumed here since output will be for A/A versus I_{sp} where $A/A^* = (r/r^*)^2$.

3. OUTPUT DESCRIPTION

As a result of the many types of analyses performed by the computer program considerable output can be generated. Since the amount, and nature, of the output will vary over a wide range, as a function of the options selected, the output descriptions will be keyed to the individual overlays (types of analyses). The sample case output in section 5 is a valuable adjunct to the output description, and should be liberally referred to.

3.1 Overlay O (Program control and summary) Output

Since all of the program input cards do not appear in formated output statements, it is recommended that a card image listing of the input cards be obtained, via control cards, at the initiation of the run.

The first output from the program is the case title. This is followed by an acknowledgement of the program directives that have been considered (GEOM, TRAJECTORY, etc.). After acknowledging the TRAJECTORY directive the trajectory information is output in tabular form.

Following the PROBLEM directive, the program enters into execution of the various overlays as directed by the SPROB input. The output produced during the execution of these overlays is discussed in subsequent subsections.

Upon completion of each of the overlays from 2.0 to 5.0, the following outputs are produced.

<u>OVERLAY 2</u>. If BAL = 1 or 2, the calculated values of P_c (psi), L^* (in.), r^* (in.), dr^*/dt (in/sec), $\dot{M}$ (slugs/sec), and η_{c^*} are printed as a function of time in seconds. A table of the average, maximum and minimum of each of the above quantities is also output. The average values are computed based on the total calculated burn time unless the following message is printed out below the table:

VALUES AT TIMES GREATER THAN _________ HAVE BEEN EXCLUDED FROM THE AVERAGE CALCULATION

The excluded points (should there be any) represent points during tail-off that might produce spurious η_{c^*} values that unduly affect the calculate average η_{c^*} value.

OVERLAY 4. If ODK = 1, or 2, a table of the one dimensional kinetic specific impulse, ISP_{ODK}, and the kinetic ISP efficiency factor, η_{kin}, are printed out as a function of nozzle area ratio.

OVERLAY 5. If TD2P = 1, or 2, a table of the calculated two dimensional, two-phase, perfect gas, specific impulse, ISP_{TD2P}, and the 2-D, two phase, I_{sp} efficiency factor, η_{TD2P}, is printed out as a function of nozzle area ratio.

If RSDØT≠0 in $ the $GEOM namelist, or if Overlay 3 (Ballistics program) has been executed and indicates that the throat erodes, then the nozzle expansion ratio will vary as a function of time.

In such cases η_{TD2P} and $I_{sp_{TD2P}}$ are time dependent. The program calculates and prints out the time averaged values of these quantities.

The program also calculates and outputs a value of η_{TD2P} to be used in the overall efficiency calculation. When there is throat erosion the use of this modified efficiency corrects the predicted overall delivered specific impulse for the fact that I_{sp} varies with expansion ratio (see subroutine SUMRY).

OVERLAY 6. If TBL = 1, or 2, a table of the incremental loss in I_{sp}, $\Delta I_{sp_{TBL}}$, is output as a function of nozzle area ratio.

After all of the individual loss calculations have been completed a summary page is printed out. Figure 3-1 reproduces a typical output summary page. A series of descriptive notes are given below. These can be correlated with the circled numbers on Figure 3-1.

Note: 1. These values are calculated when the relevant parameter in the $PROB input equals 1 or 2.

2. The calculated 2-D, two phase efficiency also includes the so-called erosion loss. The magnitude of the erosion loss (in terms of an efficiency) is equal to the ratio of η_{TD2P} (corrected for throat erosion) to η_{TD2P} (time averaged). (See summary output from TD2P module).

3. A "calculated" value of combustion efficiency is obtained only if BAL = 1, or 2 and TD2P = 1, or 2 in the $PROB namelist. The "calculated" combustion efficiency is equal to the nozzle discharge coefficient (calculated by TD2P) times the "empirical" combustion efficiency.

4. This efficiency cannot be theoretically calculated with the present program.

5. The calculated 2D 2 phase efficiency includes this effect.

6. Empirical efficiency factors are always calculated. (Except for empirical combustion efficiency which is calculated only when BAL = 1, or 2, and TD2P = 1, or 2).

7. Includes the two-phase efficiency only. If BAL ≠ 1, or 2 this efficiency will be calculated only if AVELS in $GEØM Namelist is ≠ 0.

8. If the real nozzle geometry has been altered as a result of the restrictions imposed by the TD2P program, the output value of this efficiency will be erroneous when the nozzle attachment angle (supersonic) implied by the input nozzle contour differs from the actual nozzle attachment angle. In such cases the correct value may easily be calculated by hand.

9. These values are equal to unity unless the relevant $PROB parameter equals 3, and a non-unity value has been input.

10. For each of the individual loss mechanisms, this column gives the efficiency factor selected for use in the overall efficiency calculation. The selection criteria is as follows, in order of precedence:

1. Input values.
2. Calculated values.
3. Empirical values.

11. The product of the selected efficiencies is not, in general, equal to the product of the efficiencies calculated by any <u>one</u> of the methods, as it may contain efficiencies calculated by different methods.

12. This column is a key to the method selected for use in the overall efficiency calculation. The meanings of the letters are as follows:

I - Input
C - Calculated
E - Empirical
N - Not considered (a value of unity is used in such cases)

13. The values of delivered vacuum specific impulse are equal to the theoretical specific impulse at the initial (t=0) nozzle expansion ratio multiplied

SUMMARY OF RESULTS FROM SPP COMPUTER PROGRAM   VERSION 1.1 DATED 31 JAN75

CASE TITLE EXTENDED DELTA VALIDATION CASE

**** VACUUM PERFORMANCE ****

NOTE	LOSS MECHANISM	ETA CALC 1	ETA EMPIR 6	ETA 9 INPUT	ETA 10 SELECTED	METHOD SELECTED 12
	KINETIC	1.0000	.9939	1.0000	.9939	E
1	2D-2PH	.9670 2	.9451 7	1.0000	.9470	C
2	COMB EFF	.9863 3	.9735	1.0000	.9863	C
3	SUBMERG	1.0000 4	.9921	1.0000	.9921	E
4	2-D	1.0000 5	.9767 8	1.0000	1.0000	C
PRODUCT OF ETAS		.9370	.9217	1.0000	.9199 11	

TURBULENT BOUNDARY LAYER LOSS DECREMENTS

METHOD	DELTA ISP(LBF-SEC/LBM)	
CALCULATED	1.6844	
EMPIRICAL	1.7367	
INPUT	0.0000	
VALUE SELECTED	1.6844	METHOD SELECTED C 10 12

DELIVERED VACUUM SPECIFIC IMPULSE (LBF-SEC/LBM)

METHOD	ISP(VAC) 13	
CALCULATED	287.5826	
EMPIRICAL	283.9866	14
INPUT	310.0770	
VALUE SELECTED	283.5560	

ISP DECREMENT DUE TO EXHAUSTING TO AMBIENT PRESSURE

AVE. AMBIENT PRESSURE(PSIA)	.0071	15
AVE. CHAMBER PRESSURE(PSIA)	533.6030	
AVE. EXPANSION RATIO	20.6060	
DISCHARGE COEFF.	1.0118	
DELTA ISP (LBF-SEC/LBM)	.8342	

ISP DELIVERED TO THE AVERAGE AMBIENT PRESSURE OF   .00714 PSIA IS = 282.7218 LBF-SEC/LBM

Figure 3-1.   Sample Summary Page From Program Output

by the appropriate product of efficiencies, and then decremented by the corresponding turbulent boundary layer loss.

14. The empirical delivered vacuum specific impulse does not include the so-called erosion loss-see note 2 for how to include this loss in the empirical result.

15. The average ambient pressure is the average of all points in the trajectory table. The average chamber pressure is obtained from the summary table following the ballistics calculation (or is input if a ballistics calculation is not called for). The average expansion ratio is an average based on the whole calculated burn time. The discharge coefficient is obtained from the TD2P program.

If BAL = 1, or 2, and TD2P=1 or 2, in the $PROB Namelist, a page entitled "Thrust - Time History" is output at the end of a run. The table is basically self-explanatory, however the following items should be noted:

1. The mass flow (MDOT) and the integrated mass flow (MDOT-INT), include the corresponding total mass flows (i.e. both propellant and insulation).

2. Due to inaccuracies in the input grain geometry the total integrated mass flow may not equal the known propellant (and burned insulation) weight. In such cases the calculated total impulse (F-INT) should be adjusted by the ratio of calculated to known propellant weights.

3. The average I_{sp} is the average delivered I_{sp} and will in general differ from the "I_{sp} delivered to the average ambient pressure" which appears on the aforementioned summary page.

4. The average MDOT may differ from the corresponding value in the Ballistics Ave.-Max.-Min.. Table as a result of different time bases for the two averages.

5. Negative I-DEL values appearing during tailoff do not unduly affect the calculated average, AVE. ISP = F-INT/MDOT-INT.

3.2 Overlay 2 (ODE) Output

The first line of output says that one zone is being calculated (multi-zone calculations are not permitted in the present application). The input reactants

cards are then reproduced, followed by the INSERT/OMIT cards (when applicable). The NAMELIST input is not printed out in the program's present form. The word NAMELISTS and the print out "NO $ODE VALUE GIVEN. . ." should be neglected.

A list of the species being considered in the calculation is then printed. Each species in the list is preceded by some identification such as J12/65. The J refers to JANNAF data[8]. The letter L refers to unpublished data calculated at the NASA Lewis Research Center. The number refers to the month and the year the data was published or calculated.

Following the list of species is the current value of O/F. This is followed by a listing of the enthalpies or internal energies of the total fuel and oxidant, and of the total reactant. Following this is a list of the kilogram-atom per kilogram of each element in the total fuel and oxidant, and in the total reactant.

The next output yields information regarding the iteration procedure used in obtaining equilibrium solutions. User's interested in interpreting this information should refer to Reference 1 .

The primary output of this program is basically self-explanatory. If EQL = .TRUE. in the $ODE input the results of an equilibrium rocket performance calculation will be printed out. This output contains the following:

1. Heading
2. Chamber pressure
3. Proportion of oxidant to fuel
4. Thermodynamic mixture properties and derivatives
5. Rocket performance information
6. Composition of the combustion products

Items 4, 5, and 6 are output at conditions corresponding to the chamber, throat and requested area ratios (SUPAR and SUBAR arrays). They are also output (first exit column) at the area ratio at which particle solidification begins (if applicable).

The aforementioned tables are followed by a listing of the trace species which were considered in the calculation, but which do not appear in the mole fraction table.

A table of the mass fraction of condensibles is then printed out. These values correspond to the same relative locations given in the main table.

The molecular weights of the condensibles and gas only, in the chamber, are printed. The value of the erosion parameter, β, used in the Ballistics Module throat erosion correlations, is then indicated.

The next page of output gives the results of the transport property calculations. Viscosity, MU, frozen thermal conductivity, K, and frozen Prandtl number, PR are given for the chamber and at the throat and exit plane. The power law viscosity parameters calculated for use in the TD2P program are then printed, followed by a list of the species considered in the transport property calculations.

If FRØZ = .TRUE. in the $ODE input a second series of output is generated for the results of a frozen rocket performance calculation. The output is identical to that described for the equilibrium solution, with the following exceptions:

1. There are no table entries at the area ratio corresponding to particle solidification.
2. Mole fractions are frozen and hence do not vary with location.
3. The information concerning the condensibles and transport properties is not calculated or printed out.

3.3 Overlay 3 (Grain Design and Ballistics) Output

The first output from this overlay consists of the current values of the variables in the $BAL NAMELIST. Values input directly via the $BAL NAMELIST over-ride internally generated values.

The next series of output is a repeat of the information contained in the formated input cards.

The main output from the Motor Performance Module is of two distinct types: (see sample case)

1. Results of the grain design calculations
2. Results of the ballistics calculations

Grain design results are printed at t = 0, and then each time the number of burns becomes equal to NB. Thus, it is possible that more than one ballistic display can appear between the grain design displays. The first column of the grain design output is the station number. The number of stations is NX + 1; station NX appears on a succeeding page, and station NX+1 is the plenum aft of the grain,

or the nozzle entrance. For a submerged nozzle, the nozzle entrance is artificially located at the aft end of the grain. The second column is the axial location of the station in inches. The next two columns are web positions between successive NB increments; the first is the beginning web, the second is the ending web, in inches, and the difference is equal to B10/NB10. Variations down the port stem from uneven burning. The following two columns are port areas, in sq. inches, corresponding to these two web positions. The next column is the average local grain perimeter in inches. The next column is the local volume of propellant in the interval in cubic inches. The next column is the local burn area in sq. inches, and following that is a running sum of burn area down the port. The last column is a running sum of local void volumes.

In the case of end-burning grains, where the burning follows the X-direction, results which seemingly vary with Y are artificial and should not be taken literally without interpretation. Port areas will be zero, opening to the motor area across the end-burning face; this interface will propagate upstream with time. Burn volume and local surface area also will appear to propagate upstream, being zero both upstream and downstream of the interfacial region. (Web position is really longitudinal even though the output may make it appear to be radial).

In the set of ballistics oriented output the first column is the station number, followed by a loop counter. This is followed by local values of gas density (lb/in^3), mass flux contribution (lb/in^2-sec), gas velocity (in/sec), pressure (lb/in^2), port area (in^2), weight flow contribution (lb/sec), burning rate (in/sec), cumulative web (in.), insulation area (in^2), burn area (in^2) and the axial position of the station (in.). (Again, in the case of end-burner, values appearing upstream of the burning surface are artificial).

The sequence of output appearing after the columns are time (sec.), vacuum thrust (lb.), ambient thrust (lb.), delivered specific impulse (sec.), motor stagnation pressure (lb/in^2), nozzle exit pressure (lb/in^2), nozzle exit velocity (in/sec.), insulation area exposed (in^2), burn area (in^2), throat area (in^2), head-end pressure integral (lb-sec/in^2; ignore for end-burners), aft stagnation pressure integral (lb-sec/in^2), insulation weight expended (lb.), propellant weight expended (lb.) and total impulse (lb-sec.). All integrals are up to the particular time in question. This summary output is identified by the throat node number, NX + 2.
If this module is run in a stand-alone mode the above motor performance values

will be the only ones calculated, hence, nozzle efficiency, ambient pressure, etc. must be input. If a grain design and ballistics calculation is combined with a nozzle performance calculation these thrust and impulse values should be ignored in favor of those appearing in the THRUST-TIME HISTORY (see section 3.1).

The unlabled output (6 columns) which may appear from time to time is debug print which was never removed (see subroutine MAIN3). The statement "Reference To Uncorrelated Table Number" also is debug print and states that the designated table would have been used had the associated option been exercised. It is not an indication that something is wrong.

3.4 Overlay 4 (ODK) Output

If IREQ = 1 in the $PROB NAMELIST (and ODK=1) the first output related to the kinetics solution is not from Overlay 4, but is a special equilibrium solution referred to as the "RESTRICTED EQUILIBRIUM OPTION." The format of the equilibrium output has been previously described in section 3.2.

The equilibrium output is followed by the values of temperature, pressure and velocity at the equilibrium (starting) contraction ratio (ECRAT). The species mole fractions at the initial station are then listed.

If IREQ = 0 the above output is not obtained. The output described below is obtained in all cases.

The first output from Overlay 4 is a listing of the input reaction and third body reaction rate ratio cards, as read. This is followed by a table of all the species contained in the input reaction set. A reaction table, containing information from the input reaction cards is then printed.

The next output is a table of all of the species that will be considered in the kinetic expansion solution. The number of the species, and its initial mole fraction is also given in the table.

A formated table of reaction rate ratios (or the message - ALL REACTION RATE RATIOS INPUT AS 1.0) is then printed out. This is followed by a message relating the type of nozzle geometry option which was selected and a table of the relevant wall geometry. The two values alpha and alpha-bar are the particle to gas weight flow ratio and the mass fraction of the condensed phase, respectively.

The next output describes the flow properties, nozzle geometry and chemical composition at the initial expansion ratio. This output is self-explanatory. The same quantities are then printed out at a series of axial stations. The number and location of these outputs being controlled by the print flag (JPRNT).

When the temperature becomes equal to, or less than, the solidification temperature of the metal oxide being considered (if any) a message is printed out to indicate the beginning of solidification. Likewise, when solidification is complete, a message so indicating is printed.

The note EP not reached means that the final requested expansion ratio was not reached before the solution terminated. In some cases this is due to an input error which causes abnormal termination. In many cases, however, the message is printed somewhat erroneously. In such cases the program actually has effectively reached the final expansion ratio but due to round-off error the message is still printed.

3.5 Overlay 5 (TD2P) Output

The case title card is printed followed by a list of quantities which were either internally transmitted or input in the $TD2P NAMELIST.

The following quantities are calculated in subroutine AGP. Only the mathematical symbol and units for each quantity is given here. See subroutine AGP for definitions.

Variable	Math. Symbol	Units
G(I)	$\bar{\gamma}$	-
E(I)	E_{pm}	-
CPG	C_{pg}	$ft^2/sec^2/°R$
G	γ	-
RCAP	R	$ft^2/sec^2/°R$
CPS	C_{ps}	$ft^2/sec^2/°R$
HPS	h_{ps}	$ft^2/sec^2/°R$
HPL	h_{pl}	ft^2/sec^2
HPO	h_{po}	ft^2/sec^2
PR	Pr	-
RHØGO	ρ_{go}	lbm/ft^3
B	B	-
BS	B_s	-
GSB	$\bar{\gamma}_s$	-

The specific impulse, ISP(1DOL), and exit velocity, UE(1DOL), calculated from a one dimensional zero lag analysis are output at the nozzle exit expansion ratio. The mean particle size and particle size distribution (input, or internally generated) are then printed out.

The next series of output comes from the one-dimensional inlet and transonic throat portion of the solution (see subroutine PARTIL). The output appears in the following sequence:

1. The values k and $\dot{m}_g$ for gas-particle equilibrium.
2. Initial and final conditions for the one-dimensional inlet integration (see subroutine ØNED).
3. Converged values for x_o, u_o, α, β, γ and f_1, f_2, f_3, f_4, f_5 for each transonic flow zone (see subroutine JAMES).
4. The corrected estimate for k, corrected values for x_o, u_o, α, β, and γ in the transonic zone containing the initial supersonic data line, corrected values for $\dot{m}_g$ and $\dot{m}_{p_j}$.
5. Items 2,3, and 4 are iterated twice.
6. The gas-particle flow properties P_g, ρ_g, u_g, v_g, r, z, h_{p_j}, ρ_{p_j}, u_{p_j} and v_{p_j} along the initial supersonic data line.
7. The nozzle weight flow, WDOT.
8. The nozzle discharge coefficient, CD.

A message indicating the selected wall geometry option is then printed, together with the input (or internally transmitted) nozzle geometry. A finely spaced internally calculated, table of the wall coordinates to be used in the solution is also output.

The results of the two dimensional, two phase, supersonic solution are printed out along left running characteristics. A header is printed, for identification purposes, above the output for each left running characteristic. The output may be identified as follows:

Row One:

Item	Header	Meaning	Units
L.R.C. number	LRC	left running characteristic number	none
Ident. number	ID	type of point (see below)	none

Item	Header	Meaning	Units
r	R	r position coordinate	none
z	Z	z position coordinate	none
M	MACH	Mach number	none
T_g	TG	gas temperature	°R
V_g	VG	gas velocity (scalar)	ft/sec
θ_g	THETA-G	streamline angle	degrees
T_g/T_{g_o}	TG/TGO	ratio of gas temperature to chamber temperature	none
P_g/P_{g_o}	PG/PGO	ratio of gas pressure to chamber pressure	none
ρ_g/ρ_{g_o}	DG/DGO	ratio of gas density to chamber density	none
$\sum^K \rho_{p_j}/\rho_g$	SDK/DG	ratio of total particle density to gas density	none
C_F	CF	thrust coefficient	none
I_{sp}	ISP	specific impulse	sec.
iteration no.	IT	number of iterations required	none

Rows Two through K+1

A row is printed for each particle size present at the point in question.

Item	Header	Meaning	Units
k	K	particle size number	none
Re_k	REK	particle Reynolds number	none
V_{p_k}	VPK	particle velocity (scalar)	ft/sec
θ_{p_k}	THETA-K	particle streamline angle	degrees
T_{p_k}	TPK	particle temperature	°R
ρ_{p_k}/ρ_g	DPK/DG	ratio of particle density to gas density	none

Item	Header	Meaning	Units
ρ_{p_k}/ρ_{p_o}	DPK/DPO	ratio of particle density to chamber particle density	none
r_{p_k}	RPK	particle radius	ft.

The table below relates the printed identification number to the type of point calculated:

ID	Type of Point Calculated
1	initial line point
2	interior point
3	axis point
4	Kth particle boundary point
5	wall point
6	point inserted on the previous L.R.C.
7	point inserted on the R.R.C.

The quantity IP printed out at the end of a TD2P solution is the number of mesh points on the last left running characteristic.

3.6 Overlay 6 (TBL) Output

The case title is printed, followed by a list of the current values of the $TBL NAMELIST variables. Values input in $TBL over-ride internally transmitted values.

A table of the input (or internally transmitted from TD2P) wall geometry and wall streamline mach number is then printed out.

At every printout station the program then prints six groups of quantities. (Note: DELF and DELI were added to the TBL output and do not conform to their respective group headings. These two quantities are not output until the wall slope becomes positive.)

Contour Properties

X	Axial Distance
XL	Arc length of contour up to X
Y	Radius or height of contour
DY/DX	Slope of contour

Flow Properties

M	Mach number
TE	Static temperature
TW	Wall temperature
TAW	Adiabatic wall temperature
DM/DX	Mach number gradient
UE	Velocity of fluid
PE	Static pressure

Boundary Layer

DELTA	Velocity thickness
DELTB	Temperature thickness
DELT*	Displacement thickness
THETA	Momentum thickness
PHI	Energy thickness
H	Shape factor δ^*/θ
DEL F	Thrust decrement due to boundary layer effects

Heat Transfer

HG	Heat transfer coefficient
QW	Local rate of heat transfer to wall
SUMQ	Integrated heat transfer rate to point X
FORCE	Drag force in axial or X direction
LAT. F	Force normal to X direction for two-dimensional planar flow
DEL I	I_{sp} decrement due to boundary layer effects

Internal Integrals

ZETA, I1, I2, I3, I4, I5, I6, I7, I1P, I2P, I3P

Coefficients

CF	Skin friction coefficient
CH	Stanton number
RETH	Reynolds number based on momentum thickness
REXL	Reynolds number based on arc length
REPH	Reynolds number based on energy thickness
RED*	Reynolds number based on displacement thickness

In addition, if the sonic point start procedure is used, the initial values of momentum thickness, THETAI, and energy thickness, PHII, are printed out.

After the last printout station the value of the throat radius corrected for displacement thickness, and a table of the normalized wall contour points corrected for displacement thickness are output.

3.6.1 Dimensions of Variables

There are six physical dimensions used in this program:

M = Mass
F = Force
T = Temperature
S = Time
L = Length
H = Heat

Any consistent set of units may be used with this program. If input quantities are in units consistent with those below, the output quantities will have the units indicated below.

RBAR = L x F/M x T
C_p = H/M x T
FJ = L x F/H
G = M x L/F x S^2
TE = T
PE = F/L^2
μ = M/S x L
ρ = M/L^3
UE = L/S
Re = Dimensionless
X = L
Y = L
XL = L

C_f = Dimensionless
C_H = Dimensionless
θ = L
ϕ = L
δ = L
[illegible] = L
δ^* = L
QW = H/L^2 x S
SUMQ = H/S axisymmetric flow
SUMQ = H/S x L planar flow
hG = H/L^2 x S x T
FORCE = F(F/L for 2D flow)
LAT.F = F/L

The built in values of FJ and G require use of the Foot, $Pound_M$, Second, BTU, $Pound_F$, Degree Rankine, system of units unless FJ and G are input.

For example, using the above conventions, and using the built in values of FJ and G

M = lb-m

F = lb-f

T = °R

S = sec

L = ft

H = BTU

R	= ft lb_f/lb_m °R	C_f	= dimensionless
C_p	= BTU/lb_m °R	C_H	= dimensionless
FJ	= ft lb_f/BTU	θ	= ft.
G	= (lb_m/lb_f) ft/sec^2	φ	= ft.
TE	= °R	Δ	= ft.
PE	= lb_f/ft^2	δ	= ft.
μ	= lb_m/sec ft	δ*	= ft.
ρ	= lb_m/ft^3	q	= BTU/ft^2 sec
UE	= ft/sec	Q	= BTU/sec (axisymmetric flow)
Re	= dimensionless	Q	= BTU/sec ft (planar flow)
X	= ft	h_g	= BTU/ft^2 sec °R
Y	= ft	FORCE	= Lb_f
XL	= L	LAT.P	= Lb_f

Note: When this program is used as an integrated module in the SPP Program certain constraints are placed on the units by data communicated from other modules.

4. RECOMMENDED PRACTICES AND GUIDELINES

This section has been included to provide a place for some of those comments that do not seem to belong anywhere else, but should be recorded. Thus, the following is a potpourri containing recommendations on using the SPP program, miscellaneous notes, and guidelines for selecting values for certain of the input quantities.

The input oriented comments are presented in the order in which the variables appear in Section 2. Amplifying comments, of the type contained herein, for the grain design and ballistics inputs have been integrated into the text of Sections 2.7 and 5.

The best recommendation that can be made is to encourage prospective user's of this program to carefully study this manual in order to learn the capabilities, intricacies, and limitations of the program. Time spent in this way will be repaid several fold when the user tries to run cases.

Until the user has achieved a high confidence level in running the program, it is suggested that the modules be executed one or two at a time. The output can then be examined to see if it appears to be reasonable, and that the case that has been run corresponds to the one that the user desired. This approach can save the user considerable computer time during his initial attempts to run the program.

$GEOM NAMELIST

Many of the inputs from this Namelist are automatically transferred to the relevant calculation modules. These geometry inputs can be over-ridden by direct input to a given module, but remember that such a geometry change is known only to that module.

ASUP It is suggested that some extra values of ASUP be packed around the exit plane, average expansion ratio, and any regions of particular interest, since interpolation is performed in this table. Otherwise, a reasonable number of roughly equally spaced values will suffice.

ASUB These need to be input only if subsonic information is desired (unless an ODK solution is called for, then ASUB(1) must be input equal to ECRAT).

RCURV	TD2P requires that the throat be circular with a single radius of curvature. Different upstream and downstream radii of curvature are allowed in ODK. If the throat is not circular, RCURV must be obtained by a best fit to the specified throat geometry. Values of RCURV < 1.5 should be avoided; the TD2P transonic analysis will fail for lower values.
RSDØT TBURN	These values are over-ridden by the results of the ballistics module if BAL = 1 or 2 in the $PROB Namelist.
THETAI	The transonic method in TD2P will fail if $\theta_i > 45°$.
THETA	If the real nozzle shape cannot be input due to program restrictions it is better not to try to match THETA with its actual value. Instead, one should try to select THETA to minimize the differences between the real and input nozzle shapes (see comment on THJW under $TD2 Namelist). It should be understood, however, that if THETA is not equal to its actual value the empirical 2-D efficiency calculated by the program will be erroneous.
RS(I) ZS(I) NWS	Remember that this table starts at 2, so the total number of points, NWS, is equal to the number of input points +1. Check the wall derivatives tables printed out in ODK and TD2P for wiggles. Don't try to input too many points, or get spacing to close. If table is bad (not due to input mistake) it is usually better to throw out points rather than add them.
AVELS	If BAL≠1 or 2, AVELS must be input in order to calculate an empirical two-phase efficiency.
$PROB NAMELIST	Setting ØDE, BAL, etc. equal to 3 allows the relevant loss efficiency to be input in the ETAI(I) table. This allows the user to bypass both the calculated and empirical options of the program in favor of a value obtained from a different analysis (if the user has reason to believe the present analysis is inadequate for his problem), or for any other reason.
IREQ	When this flag is input as 1 the initial data for the kinetics calculation is automatically obtained from a "restricted equilibrium" solution. Unless the user has a strong reason for wanting to input his own initial concentrations, etc. the use of IREQ=0 is not recommended. Also, if IREQ=0, the program cannot calculate η_{KIN} unless it is "fooled" by user prepared punched cards containing the $I_{sp_{RE}}$ values that are normally punched following execution of a restricted equilibrium solution.

$ODE NAMELIST — For ØDE=1, ODK≠1 and TD2P≠1, the MIX array can be used as described in Reference 1.

P(I) — For the present application the ODE program has been modified so that it can execute only rocket problems. Thus, only P(1) will be considered.

OFSKED(I)
DELH(I) — In its current application the ODE program has been modified so that only one zone can be considered.

ODK USAGE INPUT — The user is cautioned that ODK execution times become very large as pressure increases beyond about 600 psi. Fortunately, at high pressure, the kinetics loss tends to be quite small (a few tenths of a percent of loss) and the empirical relation for the kinetics efficiency can be utilized without qualms.

The ODK running times are not insignificant even at moderate pressures ($P < 600$ psi). The size of the present reaction set (Table 2-13) and the speed of the aluminum reactions are such that execution times on the order of 2-5 minutes (CDC6600) can be expected at moderate pressures. Thus, ODK should not be executed indescriminately. Its use is warranted only when the utmost accuracy (that the program is capable of) is desired, or when it is suspected that the kinetics loss may be relatively large.

A completely satisfactory set of reactions and reaction rate data for aluminized solid rocket propellants does not exist at this point in time. The set given in Table 2-13 represents the results of the limited study that was possible within the constraints of the current effort. Should the user be interested in modifying this reaction set it should be pointed out that execution time is linearly proportional to the number of reactions and proportional to the number of species to a power between 2 and 3.

With the previous comment in mind the user should use OMIT cards (section 2.6.2.1) to eliminate as many of the unimportant (from a performance standpoint) trace species as possible in the ODE restricted equilibrium solution.

RWTD
RWTU — The kinetics program allows for different upstream and downstream throat radii of curvature (the TD2P program does not). If a combined solution including both TD2P and ODK modules is to be executed (and in reality RWTD≠RWTU) it is probably not worth changing to a different nozzle shape for the ODK solution unless the downstream expansion is so rapid that the single radius (less extreme expansion) approximation would lead to serious underprediction of the kinetics loss.

RZNØRM	PWRS and PWZS are already normalized if they have come from $GEOM. Thus, RZNORM is not relevant unless ODK is run in a stand alone mode.
HI HMAX HMIN DEL	The nominal assumed values should work well in most cases. User's should not change these values without first becoming quite familiar with the ODK program; they can have a very large impact on exectuion time.
TEXPLI JF	It is recommended that these values always be input as 0 because of the speed of the aluminum reactions.
JPRNT	It is recommended that the -2 option be used. The other options (except -1) can yield voluminous output.
IDYSCI	The user is warned not to change the assumed value. Turning on this option uses alot of trees.
EPSEL	To eliminate species for the ODK solution the use of OMIT cards is somewhat preferable to EPSEL. With OMIT cards the user has direct control over which species are to be eliminated.

<u>$TD2 NAMELIST</u>

DZI DL DZMIN DTWI SAUR DR THFD EW ZI IMAX ZJ N1 VAR N2 HFD	The nominal assumed values for these variables should suffice in almost all cases. The user should be quite familiar with the TD2P program (and be unable to run a case otherwise) before venturing to change these values.
NILP	More than 20 points should not be required, but one should probably not use less than 15.
RRT	Should be greater than, or equal to, 1.5 to avoid problems in transonic solution.
THIW THJD THJW	THIW should be selected such that the Mach number at the wall initial line point is about 1.1. THJD should be set to about 3/4 of THIW. THJW must be greater than THIW (the initial line must be on the circular portion of the throat). See comment on THETA under $GEOM Namelist.
ZAX	An estimate for this quantity may be made as follows:

$$ZAX \approx 1.2\left(R_c \sin\theta_{l_w} + \frac{1 - \cos\theta_{l_w}}{\sin\theta_{l_w}}\right) \quad \text{where } \theta_{l_w} = \text{attachment exit angle}$$

This estimate is based on a first order source flow approximation.

NTBL	The nominal value should suffice.
XITBL	The results of the TBL program should not be too sensitive to this value (for further information see Reference 4).
ITØT	A value of 3 is recommended for ITØT. A larger value, while possibly a little more accurate, increases the risk of impingement.
XK PEXP XL XD	Since the particle size correlation is empirical the user is proceding at his own risk if these values are changed.

<u>$TBL NAMELIST</u>

IPRINT	Should be left = 0. IPRINT = 1 leads to voluminous output.
THETAI PHII	The solution should not be too sensitive to the value input. These thicknesses decrease as unit Reynolds number increases.
MZETA ZNSTAN TØLCFA TØLZET TØLZME	The user should be familiar with the TBL program and/or boundary layer theory before trying to change the nominal values.

5. SAMPLE CASES

The Extended Delta Motor[10] is representative of modern finocyl grain designs whose complexity warrants the use of a three dimensional grain design program. A sketch of this motor is shown in Figure 5-1.

The input and portions of the output from two sample cases based on this motor are presented in this section. The sample cases serve to facilitate program checkout, while serving as adjuncts to the input and output descriptions.

The first sample case utilizes all of the SSP program modules except for ODK. Thus, ODE, Grain Design and Ballistics, TD2P, and TBL solutions were obtained, as were complete summaries and a thrust-time history. The second sample case represents an ODK (and restricted equilibrium) solution for the Extended Delta. A complete summary performance page based on the combined first and second sample case was not available for inclusion in this manual.

The sample cases are preceded by card image listings of the input cards used to run them. The following discussion of the Grain Design and Ballistics input for the first sample case is presented to further enhance the user's understanding of this module's relatively difficult input requirements.

The first group of cards present the grain geometry input. B10-11.92 denotes the web of 11.92 inches. NB10=20 denotes the number of burn increments; its significance is the number of new geometries called by the ballistics calculations (returns to HERCULES) without interpolation. SX00 denotes taking advantage of the symmetry of the motor, and 16 represents the fact that the diametric cross-section may be divided into 16 pie-segments. Such may be done with an 8-point star, each star segment being divisible in half. The next card defines the longitudinal grain mesh; the grain goes from X01=0 to X11=45.72 inches, and is herein divided into a mesh of NX11=100 increments. Thus, ballistics answers will be output at 100 grain stations. <u>NX must be an even whole number, cannot exceed 118, and for an end-burner must be selected such that the mesh dimension</u> (0.4572 inches in this case) <u>is larger than the expected product RO*DT</u> (burn rate times input calculational time increment). The next card defines the lateral grain mesh; the grain goes from a lateral distance (radius in this case) of Y01=0 to Y11=20.00 inches, and is herein divided into a mesh of NY11=40 increments. Note that Y11

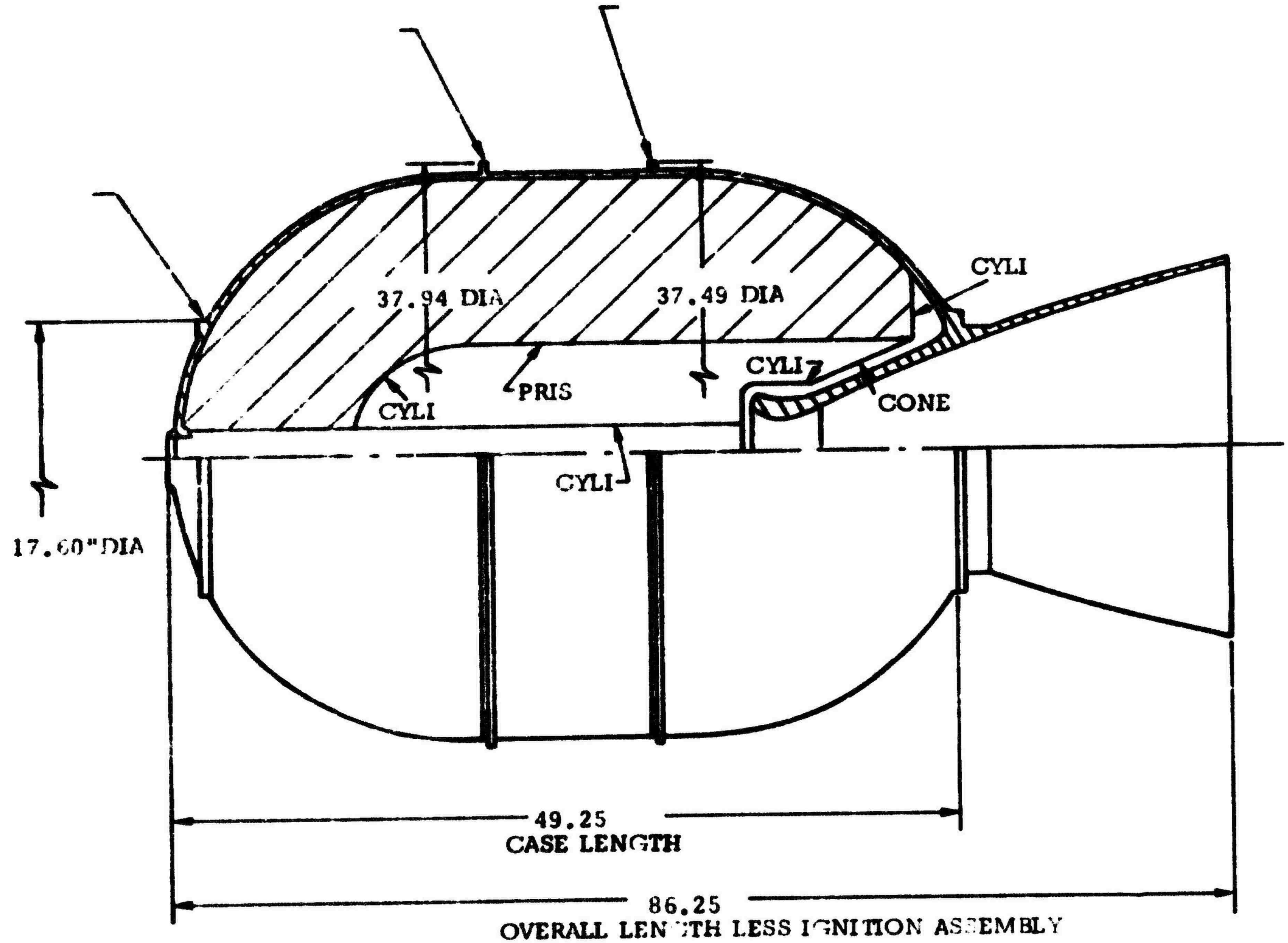


Figure 5-1. Extended Delta Motor

is selected to be larger than the motor radius; this merely assures that no dimension will be inside the motor in case of error. Note also that the computer time will be proportional to the product NX11 times NY11. A 100 x 60 matrix was the largest found to be necessary to avoid saw-tooth pressure-time trace outputs in complex grains.

The significance of the first group of cards is the definition of a geometry which is completely filled with propellant and divided into a calculational mesh. The following groups of cards define the burn surface by subtraction of volumes and codes.

The first cylinder group (CYLI) subtracts out a cylinder which fills the central port of the motor, and is tangent to the star points as soon as they begin at about 1/4 of the grain length. The centers of the circles bounding this cylinder are located at (0, 0, 0) and (46.00, 0, 0): (X10, Y10, Z10) and (X20, Y20, Z20), respectively. The cylinder may extend beyond the boundary, as done here wherein the 46.00 exceeds the 45.72. The last card sets the radius R00=1.88 in.

The second cylinder group (CYLI) subtracts out the cylinder in which the submerged nozzle throat region is snuggled. The coordinates of the defining circles are centered at (34.22, 0, 0) and (46.00, 0, 0). It may overlap the previous cylinder, as is the case here. A prior card inputs the rounded corner seen in the drawing. This is the BURN card with CR00 and 0.75 in. as the radius of the corner round. The radius of the cylinder is R00=4.55 in.

The next group labeled CONE subtracts out the conical volume that parallels the submerged nozzle exit cone. The surface of this cone, as the previous cylinder, is tangent to star points. The coordinates of the defining circles are centered at (45.72, 0, 0) and (39.40, 0, 0). The radii, respectively, are R10=7.30 in. and R20=4.55 in. Note that a cylinder is really a special case of a cone.

The next cylinder group (CYLI) subtracts out the aft volume and allows the end-face to burn. The coordinates of the defining circles are centered at (45.72, 0, 0) and (46.00, 0, 0). The radius of the cylinder is R00=12.00. (It might be noted that, if the aft end were inhibited, the second card would have to be a BURN card, with NB00 (no burn) as the proper analogy to CR00).

(As a further note, if the aft end were, instead, a division of segments of

a segmented motor, then in addition to this cylinder with a no-burn card, there must also be a division of mesh in the INIT cards. The first segment would go from X01 to X11 as here, with NX11 mesh. The first slot would go from X11 to X21 with NX21 set to -2 to key HERCULES for a segmented grain. The next segment would go from X21 to X31 with NX31 mesh, etc. The reason for the no-burn cylinder fitting the slot is that the HERCULES scheme needed to be modified to properly compute the burn-back in the slot region. Other inputs required for a slot are associated with Table 2-12. The new scheme was verified for the Lockheed Propulsion Company 156-5 motor).

The next two groups subtract out the star volumes. The first of these, labeled CYLI, deals with the circular cut at the front end of the star cavity. The second, labeled PRIS (prism), deals with the remainder.

The cylinder group, CYLI, attempts to lay a pancake cylinder inside a star so that the curved surface of the cylinder approximates the curvature of the grain. The corner round card takes into consideration the 0.25 radius of the star valley. Thus, the fitting cylinder does not have a sharp edge, but a rounded edge fitting into the star valley. Because the axis of the cylinder is toward the perpendicular to the paper, the X coordinates are constant. However, the Y and Z coordinates are offset from the plane of the paper and the centerline of the motor as appropriate to lay the cylinder inside the star as closely as possible.

The prism group, PRIS, begins at the end of the curved surface and extends down the grain for a height H00=27.80 inches. Three coordinates are required to define the prism, which lays inside the star. Again, the X-values are constant; the Y and Z values define the triangle at the constant X position, and the H00 extends this shape all the way down the grain where it overlaps the cylinders and cone at the aft end. A corner round card accounts for the curvature of the star valley. This completes the grain definition except for the outer periphery.

The next group of cards tabulates a series of pressures followed by corresponding strand burning rates. Five entries are used in this case; the maximum allowed is 99, so this presents no limitations. The number 5 appearing at location 6 on the first card below the logic card must equal the number of entries. The burn rate table is the first table at location 1. Location 3 specifies one rate for each pressure. It is good practice to input burning rates over a wide pressure

range to account for exponent variabilities, and to include a pressure higher than the expected maximum. The following group of cards is a corresponding group for pressure exponent, or slope, which is the second table at location 1.

The next group of cards tabulates the axial positions of the propellant and the corresponding propellant radii. This is the third table at location 1. Again, 99 entries are allowed; this case used 36 entries, and this number of entires must appear at location 6 on the first card below the logic card. The initial and final axial positions, zero and 45.72, must correspond to the zero and 45.72 appearing in the INIT cards (X10=0; X11=45.72). No other consistency is required. The fourth table at location I is insulation input. The input is values of time (first card) and corresponding insulation areas exposed (second card).

Time increments are the fifth table at location 1. In selecting the calculational time increment, the product of this time increment and the number of burns (NB in the grain design input) should approximate the expected burn time. This increment will impact computer time, but is of secondary importance as compared to NX and NY. The next entry is the desired intervals for output. This latter time interval can be larger except where detailed study or plotting of results are desired; it has a trivial effect on computer time. If is is desired to have variable time increments in the course of the calculations, the tables may be extended by inputting additional times and time increments associated with those times (e.g., finer increments for boost-sustain transition).

The last group of cards are Table 2-12 inputs, in the order of and with the units given therein. The 4, -1 is a required key to end table loading. The first entry, TSTOP, should be selected to be somewhat greater than the expected burn time. If TSTOP is reached before the computer time reaches DTIME, the computations will terminate, so there is the possibility that the tail-off will not be computed if TSTOP is too short. The input value of nozzle efficiency in (15) should be 1.000 for an integrated mode calculation, and can be something else for a stand-alone mode calculation. The projected nozzle area in (19) is defined by the annulus formed by the outer nozzle material shell and the open throat. Values of ambient density (23) and thermal diffusivity (26) are, respectively, 4.43×10^{-5} lb/in^3 and 3.0×10^{-4} in^2/sec. The user is cautioned to remember all -1 completion entries.

Other tables do not appear because they are not used.

Sample Case Number 1

Input Listing

```
TITLE EXTENDED DELTA VALIDATION CASE
[illegible]
 $GEOM
 ASUB(1)=2.78,    NASUB=1,
 [illegible]
 [illegible]
 ASUB(1)=[illegible].4.6.10.[illegible].[illegible],
 NASUB=6,
 [illegible]
 [illegible]
 [illegible]
 PCURV=2,
 FSI=2.141,
 ESI(2)= 1.2[illegible]
 5.[illegible].795423,
 PSI(2)=1.[illegible],2.[illegible]
 3.2605,[illegible].96263,[illegible]46147,
 NNS=11,
 AT[illegible]=2.39,   FSUB[illegible].25,
 $END
TRAJECTORY
 $TRAJ
 [illegible]=.C8,.095,.091,.1,.1,
 [illegible]=0.,18.,42.,44.,100.,
 NTJ[illegible],
 $END
PROBLEM
 $PROB
 [illegible]
 [illegible]=1,
 [illegible]=2,
 [illegible]=1,
 [illegible]=2,
 [illegible]=1,
 [illegible]=2,
 [illegible]=1,
 $END
REACTANTS
N 1.      H 4.      CL 1.0    O 4.0                .70      -70[illegible]. S 298.15
AL 1.0                                            .15      0.0     S 298.15
C 7.[illegible] H 10.509 O  0.[illegible]           .1[illegible]  [illegible]00.  S 298.15

NAMELISTS
 $ODE
 [illegible]=2.78,
 [illegible]
 [illegible]
 [illegible]
 [illegible]
 [illegible]
 [illegible](1)=100,[illegible](1)=1[illegible],
 $END
 $PAI
 $END
 EXTENDED DELTA
INIT                     A00    0.0        B10    [illegible]      A610   20.0
INIT                     SX     1[illegible].0  D   1.5
INIT                     [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  100.0
INIT                     V01    0.0        V11    20.0      [illegible]  40.0
CYL1
DATA                     X1[illegible]  [illegible].0   Y10   0.0     Z10   0.0
DATA                     X2[illegible]  4[illegible].0  Y20   0.0     Z20   0.0
DATA                     [illegible]  1.[illegible]
CYL1
[illegible]              C[illegible]  [illegible]
DATA                     [illegible]  [illegible]  Y10   0.0     Z10   0.0
DATA                     [illegible]  [illegible]  V20   0.0     Z20   0.0
DATA                     [illegible]  4.55
[illegible]
DATA                     X10    [illegible]  Y10   0.0     Z10   0.0
DATA                     X20    [illegible]  Y20   0.0     Z20   0.0
DATA                     [illegible]  7.30  [illegible]  4.55
CYL1
DATA                     X10    4[illegible]  Y10   0.0     Z10   0.0
DATA                     X20    4[illegible]  Y20   0.0     Z20   0.0
DATA                     [illegible]  12.0
CYL1
[illegible]              C[illegible]  0.25
DATA                     X10    1[illegible]  Y10   0.0[illegible]  Z10   0.7[illegible]
DATA                     X20    1[illegible]  Y20   -0.0[illegible] Z20   -1.22
DATA                     [illegible]  7.1[illegible]
[illegible]
[illegible]              C[illegible]  0.[illegible]
DATA                     [illegible]  [illegible]  Y10   [illegible]  Z10   0.7[illegible]
DATA                     [illegible]  [illegible]  Y20   [illegible]  Z20   [illegible]
DATA                     [illegible]  [illegible]  Y30   [illegible]  Z30   0.25
DATA                     [illegible]  [illegible]
```

```
COMPUTE
 1   1        1   1        6   5        -1               BURN RATE.
01  14.0     02  100.0    03  200.0    04  500.0    05  1000.0   -1
01  0.053    02  0.132    03  0.174    04  0.240    05  0.295    -1
 1   2        3   1        6   5        -1               SLOPE.
01  14.0     02  100.0    03  200.0    04  500.0    05  1000.0   -1
01  0.705    02  0.398    03  0.350    04  0.298    05  0.256    -1
 1   3        6  36       -1                             CASE GEOMETRY, DELTA
01  0.0      02  0.72     03   1.72    04   2.72    05   3.72   06  4.72
07  5.72     08  6.72     09   7.72    10   8.72    11   9.72   12  10.72
13  11.72    14  12.72    15  13.72    16  14.72    17  15.72   18  16.72
19  17.72    20  25.72    21  31.72    22  32.72    23  32.82   24  33.72
25  26.72    26  35.72    27  36.72    28  37.72    29  38.72   30  39.72
31  40.72    32  41.72    33  42.72    34  43.72    35  44.72   36  45.72      -1
01  2.4      02  6.12     03   8.44    04  10.13    05  11.24   06  12.08
07  13.66    08  14.6     09  15.24    10  15.86    11  15.36   12  16.00
13  17.22    14  17.54    15  17.9     16  18.0     17  18.18   18  18.26
19  18.37    20  18.32    21  18.32    22  18.2     23  18.29   24  16.2
25  18.06    26  17.76    27  17.44    28  17.2     29  16.8    30  16.36
31  15.84    32  15.22    33  14.46    34  13.64    35  12.64   36  11.54      -1
 1   4        6   2       -1                             INSULATION AREA.
01  0.0      02  41.0     -1
01  0.0      02  4960.0   -1
 1   5       -1                                          TIME INC.
 1   1.0     -1
 1   2.0     -1
 6  -1        5   1       -1
01 50.0      02  0.05     03 0.001     04           05             06   .09
 7  2.0       8 1.0        9 3.0       10 16.0      11 102.0       12 650.0
13 0.75      14  500.0    15 1.0       16  0.0028   17  0.0        18 0.333
19 148.0     20   1.0     21 0.0068    22    53.0   23 0.000044    24 0.3
25 870.0     26  0.0003   -1

END OF PROGRAM
 $TOP
 ITOT=3,
 ZAK=0.7,
 XITM=-6,
 $END
 $VRL
 IPRINT=9,
 TOLAI=0.0001,
 PHI=0.0001,
 $END
```

TITLE EXTENDED DELTA VALIDATION CASE

SBEM

TRAJECTORY

TRAJECTORY INFORMATION

TIME(SEC)	P-AMB(PSIA)
0.	.800000E-01
18.0000	.950000E-01
32.0000	.980000E-01
44.0000	.100000
100.000	.100000

PROBLEM

[illegible]

NO OTHER VALUE GIVEN FOR CP, CVRAT, FA, OR EPST

SPECIES BEING CONSIDERED IN THIS SYSTEM

[illegible]	[illegible]	[illegible]	ALCL3	[illegible]	AL	[illegible]	ALCL	[illegible]	ALCL2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ALCL3	[illegible]	ALH	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ALOH	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ALZO	[illegible]	ALZO2	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	CLSI	[illegible]	C	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CH	[illegible]	CH2	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CO2	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	HALO	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	O3	[illegible]	[illegible]	[illegible]	[illegible]

EFFECTIVE OXIDANT

MIXTURE

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION

PC = 961.0 PSIA

	CHEMICAL FORMULA				WT FRACTION (SEE NOTE)	ENTHALPY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	N [illegible]	H 4.00000	CL 1.00000	O 4.00000	.70000	-70690.000	S	298.15	-0.0000
FUEL	AL [illegible]				.18000	0.000	S	298.15	-0.0000
FUEL	C [illegible]	H 10.96900	C .09000		.10000	11700.000	S	298.15	-0.0000

O/F=0. PERCENT FUEL=0. EQUIVALENCE RATIO= .1605E+01 STOIC MIXTURE RATIO=0. DENSITY=0.

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7[illegible]	6.0[illegible]	1[illegible]	7.[illegible]	21.056	3[illegible]	67.[illegible]	107.[illegible]	20[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MOL WT(MIX)	25.174	21.523	25.952	25.306	25.017	25.050	25.430	25.591	26.C17	26.622

MOLE FRACTIONS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN .000005 FOR ALL ASSIGNED CONDITIONS

[illegible]	[illegible]	[illegible]	[illegible]	ALN[illegible]	ALN	AL2CL[illegible]	AL2O2	C(S)	C
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CH2	CH3	CH4	CN	CNN
[illegible]	[illegible]	[illegible]	C2CL2	[illegible]	C2H2	C2H4	C2N	C2N2	C2O
[illegible]	[illegible]	[illegible]	CS	CLCN	CLO2	CL2O	HALO	HALO	HO2
[illegible]	[illegible]	[illegible]	NCO	NOCL	NO2	NO2CL	N2H4	N2O	N2O4

[illegible] .301640 .302234 .302313 .302315

[illegible] CHANGE[illegible] 10[illegible] 12

NOTE. WEIGHT FRACTION [illegible] FUEL AND OF OXIDANT IN TOTAL OXIDANTS

FROZEN TRANSPORT PROPERTIES CALCULATED FROM EQUILIBRIUM CONCENTRATIONS

STATION	MU (LBF-SEC/FT**2)	K (LBF/SEC-DEG R)	PR
CHAMBER	.1[illegible]E-05	.51327947E-01	.[illegible]E+00
THROAT	.1[illegible]E-05	.47169158E-01	.45595532E+00
EXIT	.1[illegible]E-05	.31499995E-01	.55020051E+00

VISCOSITY EXPONENT (OMEGA) FOR THE FORM MU=MUREF*(T/TREF)**OMEGA IS .67175
MUREF FOR INPUT TO TDK = .51135336E-04 LBM/(FT-SEC)

SPECIES CONSIDERED IN TRANSPORT PROPERTIES CALCULATIONS

AL	ALCL	ALCL3	ALN
ALF?	C	CCL	CCL2
[illegible]	CCL4	CH	CH4
[illegible]	CO	CO2	C2
C2H?	C2H?	C2N2	CL
[illegible]	[illegible]	CL2	H
[illegible]	HCN	H2	H2O
H2F2?	N	NH	NH3
[illegible]	[illegible]	N2	N2O
C	[illegible]	O2	

THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION

PC = 561.0 PSIA

	CHEMICAL FORMULA				WT FRACTION (SEE NOTE)	ENTHALPY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	N 1.00000	H 4.00000	CL 1.00000	O 4.00000	.70000	-70690.000	S	298.15	-0.0000
FUEL	AL 1.00000				.16000	0.000	S	298.15	-0.0000
FUEL	C 1.01900	H 10.50500	O .09900		.14000	11700.000	S	298.15	-0.0000

O/F=0. PERCENT FUEL=0. EQUIVALENCE RATIO=.1805E+01 STOIC MIXTURE RATIO=0. DENSITY=0.

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7711	1.0406	8.3073	23.213	43.343	81.673	204.93	340.60
P, PSIA	561.0	316.7	539.1	67.53	24.17	13.14	6.865	2.738	1.607
T, DEG R	6351	5935	6311	4266	3559	3223	2350	2413	2103
H, BTU/LB	-728.5	-969.2	-745.1	-1515.6	-1807.2	-1946.7	-2099.9	-2270.1	-2369.1
S, BTU/(LB)(R)	2.3382	2.3382	2.3382	2.3382	2.3382	2.3382	2.3382	2.3382	2.3382
DEN (LBM/FT3)	.235	.146	.228	.404E-01	.175E-01	.108E-01	.612E-02	.268E-02	.167E-02
M, MOL WT	27.263	27.263	27.263	27.263	27.263	27.263	27.263	27.263	27.263
CP, BTU/(LB)(R)	.4425	.4303	.4423	.4290	.4193	.4142	.4076	.3985	.3932
GAMMA (S)	1.1972	1.1991	1.1173	1.2053	1.2104	1.2136	1.2176	1.2239	1.2270
SON VEL, FT/SEC	3630.5	3455.5	3622.8	30[illegible].8	2802.4	2673.7	2515.9	2320.8	2213.4
MACH NUMBER	0.0000	1.0000	.2584	2.0949	2.6215	2.9232	3.2925	3.7915	4.0884
VEL, FT/S	0.	34[illegible]	935.	6275.	734[illegible].	7807.	8284.	8800.	9049.
AE/AT		1.0000	2.3400	2.0700	4.0000	6.3000	10.000	20.000	30.000
CSTAR, FT/SEC		5125	5125	5125	5125	5125	5125	5125	5125
CF		.677	.182	1.225	1.435	1.523	1.616	1.717	1.765
IVAC, LBF-SEC/LB		197.8	[illegible]	233.4	255.9	266.1	277.0	289.0	295.0
I, LBF-SEC/LBM		107.8	29.1	195.0	228.3	242.3	257.5	273.5	281.3

MOLE FRACTIONS

AL	.0[illegible]	[illegible]	.[illegible]3246	ALCL2	.003436	ALCL3	.000144
ALH	.0[illegible]	[illegible]	.[illegible]0138	ALOCL	.001499	ALOH	.000427
ALCL2	.[illegible]	[illegible]	.[illegible]3530	AL2O	.000027	AL2O3(L)	.009171
CH2O	.0[illegible]	CO	.2[illegible]11	COCL	.000038	CO2	.012962
CL	.[illegible]	[illegible]	.[illegible]	CL2	.000016	H	.035446
HCL	.[illegible]	[illegible]	.000[illegible]	HCO	.000020	HNO	.000001
H2	.[illegible]	[illegible]	.[illegible]	N	.000009	NH	.000009
NH2	.[illegible]	[illegible]	.[illegible]	[illegible]	.000428	N2	.075366
C	.[illegible]	[illegible]	.0[illegible]	[illegible]	.000075		

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN .000005 FOR ALL ASSIGNED CONDITIONS

AL(S)	AL(L)	ALCL (S)	ALCL3(L)	ALN(S)	ALN	AL2CL6	AL2O2	C(S)	C
CCL	[illegible]	CCL3	CCL4	CH	CH2	CH3	CH4	CN	CNN
CN2	[illegible]	C2	C2CL2	C2H	C2H2	C2H4	C2N	C2N2	C2O
C3	C3O2	C4	C5	CLCN	CLO2	CL2O	HALO	HNCO	HO2
H2O(S)	H2O(L)	F2O2	NCO	NOCL	NO2	NO2CL	N2H4	N2O	N2O4
N3	O3								

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

```
SPAL
NPRES   =  1.
PC      =  C.3AC9??.????16E+C3,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,
CSTART  =  ?.?21??4??+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
TFT     =  0.335167222222?2E+C4,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
CPG     =  C.5672853155R9R2E+C1,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
CPW     =  C.111311314355?6E+07,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
CAW     =  C.114269F+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
RMG     =  C.3667993272C        ..  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
RMN     =  C.1?4C4329455?      01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
RML     =  C.5?9356346933?3E-05,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
RCP     =  C.??7?5?6??29211IE+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
RA      =  C.??5565E+0?,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
*       =  0.33 ?97392965?5E+C1,  0.2141F+01,  0.11RR95CCCC0727E+02,
UTIME   =  ?.??+01,
RMAL    =   .
??      =  ?.??9?3??3?01?E-0?,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,
NNCZ    =  1.
$END
EXTENDED DATA
INIT           ???   0.000?        810    11.9200        NP10    20.0000
INIT           ???   1?.??0?       0**     1.0000        **      -0.0000
INIT           ???   ?.???0        X11    45.7?00        NX11   100.0000
INIT           ? ?   ?.???0        Y11    ?0.0000        NY11    40.0000

CYLI           **    -?.??0?       **     -0.0000        **      -0.0000
DATA           X1?   ?.??00        Y10     0.0000        Z10      0.0000
DATA           X2?   4?.??00       Y20     0.0000        Z20      0.0000
DATA           R**   1.8?00        **     -0.0000        **      -0.0000

CYLI           **    -0.0000       **     -0.0000        **      -0.0000
PUSH           C***   .7500        **     -0.0000        **      -0.0000
DATA           X10   34.2200       Y10     0.0000        Z10      0.0000
DATA           X20   4?.??00       Y2?     0.0000        Z20      0.0000
DATA           R**   4.5500        **     -0.0000        **      -0.0000

CYLI           **    -0.0000       **     -0.0000        **      -0.0000
DATA           X10   45.7?00       Y10     0.0000        Z10      0.0000
DATA           X20   35.??00       Y20     0.0000        Z20      0.0000
DATA           R10   ?.?C00        R20     4.5500        **      -0.0000

CYLI           **    -0.0000       **     -0.0000        **      -0.0000
DATA           X10   45.7000       Y10     0.0000        Z10      0.0000
DATA           X20   46.0000       Y20     0.0000        Z20      0.0000
DATA           R**   12.0000       **     -0.0000        **      -0.0000

CYLI           **    -0.0000       **     -0.0000        **      -0.0000
PUSH           C***   .2500        **     -0.0000        **      -0.0000
DATA           X10   11.9200       Y10      .3400        Z10       .7800
DATA           X20   17.9200       Y20    -.3400        Z20     -1.2200
DATA           R**   7.1800        **     -0.0000        **      -0.0000

SPIS           **    -0.0000       **     -0.0000        **      -0.0000
PUSH           C***   .2500        **     -0.0000        ?       -0.0000
DATA           X10   31.8200       Y10      .0?00        Z??       .7800
DATA           X20   31.8200       Y20     7.0400        Z2?     -2.9000
DATA           R30   ?1.8200       Y30     7.2200        Z30      .?2?0
```

```
LOGIC         BURN RATE,
                1                       3      1                  6                    -1
  DATA    1       14.[illegible]        3       100.000           6      200.000        -1     500.000      5    1000.000     -1
  DATA    1         .[illegible]        2          .132           3         .174         4        .240      5        .255     -1

LOGIC         SLOPE,
                2                       3      1                  6    5               -1
  DATA    1       14.[illegible]        3       100.000           6      200.000        -1     500.000      5    1000.000     -1
  DATA    1         .[illegible]        2          .348           3         .350         4        .298      5        .298     -1

LOGIC         CASE GEOMETRY, DELTA
          1     3                       6     36                 -1
  DATA    1   [illegible]               2          .720           3        1.720         4       2.720      5       3.720      6      4.720  -0
  DATA    7   [illegible]               8         6.720           9        7.720        10       8.720     11       9.720     12     10.720  -0
  DATA   13   11.[illegible]           14        12.720          15       13.720        16      14.720     17      15.720     18     16.720  -0
  DATA   19   17.[illegible]           20        2[illegible].720 21      31.720        22      32.720     23      32.420     24     33.720  -0
  DATA   25   34.[illegible]           26        35.720          27       36.720        28      37.720     29      38.720     30     39.720  -0
  DATA   31   [illegible]              32        41.720          33       42.720        34      43.720     35      44.720     36     45.720  -0
  DATA    1   [illegible]               2         6.120           3        8.443         4      10.130      5      11.520      6     12.600  -0
  DATA    7   11.[illegible]            8        15.400           9       15.240        10      15.400     11      16.300     12     16.600  -0
  DATA   13   17.[illegible]           14        17.560          15       17.800        16      18.000     17      18.180     18     18.200  -0
  DATA   19   [illegible]              20        18.370          21       18.320        22      18.200     23      18.290     24     18.200  -0
  DATA   25   18.[illegible]           26        17.760          27       17.400        28      17.200     29      16.800     30     16.300  -0
  DATA   31   [illegible]              32        15.220          33       14.460        34      13.640     35      12.640     36     11.540  -1

LOGIC         INSULATION AREA,
          1     4                       6      2                 -1
  DATA    1        0.[illegible]        2        41.000          -1
  DATA    1        [illegible]          ?      4963.000          -1

LOGIC         TIME INC.
                5                      -1
  DATA    1        [illegible]         -1
  DATA    1        [illegible]         -1

LOGIC
          4    -1                       5      1                 -1
  DATA    1   [illegible]               2          .050           3         .001         4      -0.000      5      -0.000      6       .000  -0
  DATA    7   [illegible]               8         1.000           9        3.000        10      16.000     11     102.000     12    298.000  -0
  DATA   13   [illegible]              14     [illegible]        15        1.000        16        .003     17        .040     18       .003  -0
  DATA   19   146.[illegible]          20         1.000          21         .007        22      53.000     23        .000     24       .300  -0
  DATA   25   873.[illegible]          26          .000          -1
```

	STATION	RO MIN	RI MAX	AREA MIN	AREA MAX	AVG PERIM	BURN VOL	AVG SURF	TOTAL SURF	VOID VOL
1	0.	0.	5.5530E-01	1.1600E+01	1.[illegible]E+01	1.1123E+01	0.	0.	0.	0.
2	6.572[illegible]E-01	0.	5.9530E-01	9.3741E+00	1.5701E+01	1.1123E+01	3.0301E+00	5.0040E+00	5.0040E+00	7.7260E+00
3	[illegible]	0.	5.5530E-01	6.5476E+00	1.5275E+01	1.1120E+01	3.0301E+00	5.0040E+00	1.0108E+01	1.4807E+01
4	1.17[illegible]	0.	5.5500E-01	7.4523E+00	1.4281E+01	1.1120E+01	3.0301E+00	5.0040E+00	1.5252E+01	2.1504E+01
5	[illegible]	0.	5.5530E-01	7.3677E+00	1.3775E+01	1.1120E+01	3.0301E+00	5.0040E+00	2.0336E+01	2.[illegible]E+01
6	[illegible]	0.	5.5600E-01	1.2220E+01	1.8647E+01	1.1120E+01	3.0301E+00	5.0040E+00	2.5420E+01	3.5520E+01
7	[illegible]	0.	5.5530E-01	7.7179E+00	1.[illegible]E+01	1.1120E+01	3.0301E+00	5.0040E+00	3.0504E+01	4.2115E+01
8	[illegible]	0.	5.9530E-01	3.6[illegible]E+00	1.5217E+01	1.1120E+01	3.0301E+00	5.0040E+00	3.5560E+01	4.[illegible]E+01
9	[illegible]	0.	5.5530E-01	1.2940E+01	1.9502E+01	1.1120E+01	3.0301E+00	5.0040E+00	4.0672E+01	5.7609E+01
10	[illegible]	0.	5.5530E-01	1.4649E+01	2.1[illegible]E+01	1.1120E+01	3.0301E+00	5.0040E+00	4.5750E+01	6.7[illegible]E+01
11	[illegible]	0.	5.9530E-01	1.[illegible]E+01	1.[illegible]E+01	1.1120E+01	3.0301E+00	5.0040E+00	5.0040E+01	7.6[illegible]E+01
12	[illegible]	0.	5.5590E-01	1.[illegible]E+01	2.1107E+01	1.1120E+01	3.0301E+00	5.0040E+00	5.5924E+01	8.5500E+01
13	[illegible]	0.	5.5530E-01	1.3290E+01	1.9923E+01	1.1120E+01	3.0301E+00	5.0040E+00	6.1008E+01	9.4940E+01
14	[illegible]	0.	5.9530E-01	1.0465E+01	1.7603E+01	1.1120E+01	3.0301E+00	5.0040E+00	6.6092E+01	1.0340E+02
15	[illegible]	0.	5.5600E-01	7.1655E+00	1.3793E+01	1.1120E+01	3.0301E+00	5.0040E+00	7.1170E+01	1.1040E+02
16	[illegible]	0.	5.5530E-01	1.1554E+01	1.6102E+01	1.1120E+01	3.0301E+00	5.0040E+00	7.6260E+01	1.1771E+02
17	[illegible]	0.	5.5530E-01	1.[illegible]E+01	1.9507E+01	1.1120E+01	3.0301E+00	5.0040E+00	8.1344E+01	1.2[illegible]E+02
18	[illegible]	0.	5.5530E-01	8.6[illegible]E+00	1.5[illegible]E+01	1.1120E+01	3.0301E+00	5.0040E+00	8.6420E+01	1.3[illegible]E+02
19	[illegible]	0.	5.9530E-01	8.[illegible]E+00	1.5525E+01	1.1120E+01	3.0301E+00	5.0040E+00	9.1512E+01	1.41[illegible]E+02
20	[illegible]	0.	5.9530E-01	1.3594E+01	1.7227E+01	1.1120E+01	3.0301E+00	5.0040E+00	9.6590E+01	1.4[illegible]E+02
21	[illegible]	0.	5.5600E-01	8.[illegible]E+00	1.4729E+01	1.1120E+01	3.0301E+00	5.0040E+00	1.0168E+02	1.5[illegible]E+02
22	[illegible]	0.	5.5530E-01	9.5[illegible]E+00	1.6014E+01	1.1120E+01	3.0301E+00	5.0040E+00	1.0676E+02	1.6[illegible]E+02
23	[illegible]	0.	5.9530E-01	9.8572E+00	1.6315E+01	1.1120E+01	3.0301E+00	5.0040E+00	1.1105E+02	1.7[illegible]E+02
24	[illegible]	0.	5.5530E-01	7.3[illegible]E+00	1.4[illegible]E+01	1.1120E+01	3.0301E+00	5.0040E+00	1.1693E+02	1.7770E+02
25	[illegible]	0.	5.5[illegible]E-01	1.4[illegible]E+01	4.0775E+01	4.3[illegible]E+01	7.4[illegible]E+00	1.2430E+01	1.2437E+02	1.9[illegible]E+02
26	[illegible]	0.	5.9530E-01	2.[illegible]E+01	4.5530E+01	4.1532E+01	1.1550E+01	1.9[illegible]E+01	1.4870E+02	2.1307E+02
27	[illegible]	0.	5.5530E-01	2.5175E+01	5.5015E+01	4.[illegible]E+01	1.2[illegible]E+01	2.0[illegible]E+01	1.6[illegible]E+02	2.[illegible]E+02
28	[illegible]	0.	5.5[illegible]E-01	3.7420E+01	6.5422E+01	5.3023E+01	1.4300E+01	2.3[illegible]E+01	1.9311E+02	2.6[illegible]E+02
29	[illegible]	0.	[illegible]	[illegible]	7.2[illegible]E+01	6.01[illegible]E+01	1.5[illegible]E+01	2.50[illegible]E+01	2.1[illegible]E+02	2.[illegible]E+02
30	[illegible]	0.	[illegible]	[illegible]	7.7[illegible]E+01	6.[illegible]E+01	1.7[illegible]E+01	2.[illegible]E+01	2.[illegible]E+02	3.2[illegible]E+02
31	[illegible]	0.	[illegible]	[illegible]	[illegible]	7.3[illegible]E+01	1.9[illegible]E+01	3.[illegible]E+01	2.[illegible]E+02	3.[illegible]E+02
32	[illegible]	0.	[illegible]	[illegible]	[illegible]	7.[illegible]E+01	2.[illegible]E+01	3.3[illegible]E+01	3.1[illegible]E+02	4.[illegible]E+02
33	[illegible]	0.	[illegible]	[illegible]	[illegible]	8.11[illegible]E+01	2.1223E+01	3.5[illegible]E+01	3.[illegible]E+02	4.4[illegible]E+02
34	[illegible]	0.	[illegible]	[illegible]	9.2[illegible]E+01	8.1707E+01	2.2167E+01	3.7[illegible]E+01	3.[illegible]E+02	4.[illegible]E+02
35	[illegible]	0.	[illegible]	[illegible]	9.2[illegible]E+01	8.2[illegible]E+01	2.2[illegible]E+01	3.7[illegible]E+01	4.[illegible]E+02	5.[illegible]E+02
36	[illegible]	0.	[illegible]	[illegible]	9.5[illegible]E+01	8.[illegible]E+01	2.3[illegible]E+01	3.9[illegible]E+01	4.[illegible]E+02	5.7714E+02
37	[illegible]	0.	[illegible]	[illegible]	9.7737E+01	8.[illegible]E+01	2.[illegible]E+01	4.[illegible]E+01	5.[illegible]E+02	6.[illegible]E+02
38	[illegible]	0.	5.9530E-01	4.5900E+01	9.8[illegible]E+01	8.8[illegible]E+01	2.4173E+01	4.[illegible]E+01	5.[illegible]E+02	6.[illegible]E+02
39	[illegible]	0.	5.5530E-01	4.66[illegible]E+01	9.[illegible]E+01	8.9234E+01	2.4291E+01	4.[illegible]E+01	5.8[illegible]E+02	7.1[illegible]E+02
40	[illegible]	0.	5.5530E-01	4.71[illegible]E+01	1.0045E+02	8.9[illegible]E+01	2.43[illegible]E+01	4.[illegible]E+01	6.[illegible]E+02	7.5[illegible]E+02
41	[illegible]	0.	5.5530E-01	4.92[illegible]E+01	1.0252E+02	8.9[illegible]E+01	2.437[illegible]E+01	4.[illegible]E+01	6.[illegible]E+02	8.[illegible]E+02
42	[illegible]	0.	[illegible]	[illegible]	1.0[illegible]E+02	8.94[illegible]E+01	2.4363E+01	4.0877E+01	7.0[illegible]E+02	8.[illegible]E+02
43	[illegible]	0.	[illegible]	[illegible]	1.0252E+02	8.94[illegible]E+01	2.4363E+01	4.0877E+01	7.[illegible]E+02	8.977[illegible]E+02
44	[illegible]	0.	[illegible]	[illegible]	1.0252E+02	[illegible]	2.4363E+01	4.0877E+01	7.[illegible]E+02	9.[illegible]E+02
45	[illegible]	0.	[illegible]	[illegible]	1.0252E+02	8.94[illegible]E+01	2.4363E+01	4.0877E+01	8.[illegible]E+02	9.[illegible]E+02
46	[illegible]	0.	[illegible]	[illegible]	1.0252E+02	8.94[illegible]E+01	2.4363E+01	4.0877E+01	8.7223E+02	1.[illegible]E+03
47	[illegible]	0.	[illegible]	[illegible]	1.0252E+02	8.94[illegible]E+01	2.4363E+01	4.0877E+01	9.[illegible]E+02	1.0[illegible]E+03
48	[illegible]	0.	[illegible]	[illegible]	1.0252E+02	8.94[illegible]E+01	2.4363E+01	4.0877E+01	9.5[illegible]E+02	1.1[illegible]E+03
49	2.15[illegible]	0.	5.5530E-01	[illegible]	1.0252E+02	8.9438E+01	2.4363E+01	4.0877E+01	9.9[illegible]E+02	1.17[illegible]E+03
50	2.24[illegible]	0.	5.5530E-01	4.9235E+01	1.0252E+02	8.9438E+01	2.4363E+01	4.0877E+01	1.0357E+03	1.22[illegible]E+03

	STAT-PCS	RO MIN	RO MAX	AREA MIN	AREA MAX	AVG PERIF	BURN VEL	AVG SURF	TOTAL SURF	VCLU VOL
51	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9403E+01	2.4303E+01	4.0877E+01	1.0765E+03	1.2727E+03
52	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.1175E+03	1.3190E+03
53	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.1564E+03	1.3605E+03
54	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.1952E+03	1.4123E+03
55	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.2461E+03	1.4592E+03
56	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.2813E+03	1.5071E+03
57	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.3219E+03	1.5540E+03
58	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.3628E+03	1.6008E+03
59	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.4036E+03	1.6477E+03
60	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.4445E+03	1.6946E+03
61	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.4853E+03	1.7414E+03
62	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.5262E+03	1.7883E+03
63	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.5671E+03	1.8352E+03
64	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.6080E+03	1.8821E+03
65	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.6489E+03	1.9290E+03
66	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.6898E+03	1.9759E+03
67	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.7307E+03	2.0227E+03
68	[illegible]	0.	5.9633E-01	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.7715E+03	2.0696E+03
69	[illegible]	0.	5.9633E-01	4.5235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.8124E+03	2.1165E+03
70	[illegible]	0.	[illegible]	4.9235E+01	1.0252E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.8533E+03	2.1633E+03
71	[illegible]	0.	[illegible]	4.8608E+01	1.0177E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.8942E+03	2.2100E+03
72	[illegible]	0.	5.9633E-01	4.7557E+01	1.0384E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.9351E+03	2.2568E+03
73	[illegible]	0.	5.9633E-01	4.8373E+01	1.0106E+02	8.9408E+01	2.4303E+01	4.0877E+01	1.9759E+03	2.3026E+03
74	[illegible]	0.	[illegible]	4.7C63E+01	1.0049E+02	8.9408E+01	2.4303E+01	4.3077E+01	2.0180E+03	2.3490E+03
75	[illegible]	0.	[illegible]	4.7C45E+01	1.0022E+02	1.3250E+02	2.0132E+01	4.1000E+01	2.0607E+03	2.3987E+03
76	[illegible]	0.	[illegible]	[illegible]	[illegible]	[illegible]	1.9973E+01	4.1002E+01	2.1017E+03	2.4477E+03
77	[illegible]	0.	5.9633E-01	7.6121E+01	1.1755E+02	6.9542E+01	1.6692E+01	3.5514E+01	2.1391E+03	2.4905E+03
78	[illegible]	0.	[illegible]	8.1457E+01	1.2178E+02	6.7034E+01	1.8435E+01	3.1363E+01	2.1660E+03	2.5300E+03
79	[illegible]	0.	[illegible]	7.7C49E+01	1.1737E+02	6.7654E+01	1.8435E+01	3.0931E+01	2.1970E+03	2.5500E+03
80	[illegible]	0.	[illegible]	7.5967E+01	1.1628E+02	6.7654E+01	1.8435E+01	3.0931E+01	2.2260E+03	2.6030E+03
81	[illegible]	0.	[illegible]	8.3112E+01	1.2003E+02	6.7654E+01	1.8435E+01	3.0931E+01	2.2579E+03	2.7170E+03
82	[illegible]	0.	[illegible]	8.C673E+01	1.2103E+02	6.7654E+01	1.8435E+01	3.0931E+01	2.2903E+03	2.7750E+03
83	[illegible]	0.	[illegible]	7.6546E+01	1.1557E+02	6.7654E+01	1.8435E+01	3.0931E+01	2.3213E+03	2.8274E+03
84	[illegible]	0.	[illegible]	7.5277E+01	1.1660E+02	6.7654E+01	1.8435E+01	3.0931E+01	2.3522E+03	2.8808E+03
85	[illegible]	0.	[illegible]	[illegible]	1.2277E+02	6.7654E+01	1.9435E+01	3.0931E+01	2.3831E+03	2.9350E+03
86	[illegible]	0.	5.9633E-01	[illegible]	1.1526E+02	6.7654E+01	1.8435E+01	3.0931E+01	2.4141E+03	2.9901E+03
87	[illegible]	0.	5.9633E-01	7.9321E+01	1.1986E+02	6.8891E+01	1.8570E+01	3.1160E+01	2.4452E+03	3.0451E+03
88	[illegible]	0.	[illegible]	8.4519E+01	1.2479E+02	6.7570E+01	1.8030E+01	3.1194E+01	2.4784E+03	3.1000E+03
89	[illegible]	0.	[illegible]	8.7415E+01	1.2353E+02	5.3124E+01	1.7607E+01	2.9077E+01	2.5083E+03	3.1530E+03
90	[illegible]	0.	[illegible]	9.4527E+01	1.3284E+02	6.4342E+01	1.7372E+01	2.9140E+01	2.5335E+03	3.2100E+03
91	[illegible]	0.	[illegible]	9.7201E+01	1.3433E+02	6.2162E+01	1.7264E+01	2.8920E+01	2.5641E+03	3.2705E+03
92	[illegible]	0.	[illegible]	[illegible]	[illegible]	6.6530E+01	1.7257E+01	2.8955E+01	2.5953E+03	3.3275E+03
93	[illegible]	0.	5.9633E-01	1.1574E+02	[illegible]	5.6534E+01	1.6771E+01	2.8149E+01	2.6261E+03	3.3826E+03
94	[illegible]	0.	5.9633E-01	1.2125E+02	1.4903E+02	5.3283E+01	1.5715E+01	2.6032E+01	2.6497E+03	3.4329E+03
95	[illegible]	0.	5.9633E-01	1.2125E+02	1.5471E+02	5.3681E+01	1.5112E+01	2.5355E+01	2.6742E+03	3.4725E+03
96	[illegible]	0.	5.9633E-01	1.3824E+02	1.6303E+02	5.3324E+01	1.4869E+01	2.4607E+01	2.6977E+03	3.5419E+03
97	[illegible]	0.	5.9600E-01	1.4559E+02	1.7235E+02	5.7152E+01	1.5354E+01	2.5255E+01	2.7230E+03	3.6146E+03
98	[illegible]	0.	5.9600E-01	[illegible]	1.7533E+02	5.9612E+01	1.4468E+01	2.4400E+01	2.7474E+03	3.6907E+03
99	[illegible]	0.	5.9633E-01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.7702E+03
100	4.4826E+01	0.	5.9635E-01	1.4923E+02	1.7567E+02	5.1408E+01	1.3784E+01	2.3076E+01	2.7705E+03	3.8515E+03

00	4.5283E+01	0.	5.9503E-01	1.6004E+03	4.5563E+02	4.9595E+02	7.4576E+01	1.2513E+02	2.6956E+03	3.9967E+03

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01  4.5729E+01  0.          5.5500E-01  4.1837E+02  4.1837E+02  0.          6.7572E+01  1.1334E+02  3.0090E+03  4.1985E+03
REFERENCE TO UNCORRELATED TABLE NUMBER   6   0
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REFERENCE TO UNCORRELATED TABLE NUMBER 8 0

.5017E+06	.1441E+02	.5140E+03	.5110E+03	.1000E+01	.2394E-01
[illegible]	.1441E+02	.5177E+03	.5179E+03	.1000E+01	.1173E-01
[illegible]	.1441E+02	.5189E+03	.5194E+03	.1000E+01	[illegible]
.5017E+06	.1441E+02	.5204E+03	.5207E+03	.1000E+01	.2643E-02

ICE	2	T	F	FD	ISP	PT	PE	VE	AB1	AA	APR
		2.3[illegible]E+03	1.61[illegible]E+06	1.61[illegible]E+34	2.9[illegible]E+02	5.20[illegible]E+02	1.5456E+00	1.3[illegible]E+05	3.	3.0[illegible]E+03	1.44[illegible]E+01
		P	PC	[illegible]	[illegible]	PO					
		5.22[illegible]E+02	5.2[illegible]E+02	2.93[illegible]E-02	4.7[illegible]E+01	1.1[illegible]E+34					

	STAT-PCS	[illegible]	[illegible] MAX	AREA MIN	AREA MAX	AVG PERIF	WORK VOL	AVG SURF	TOTAL SURF	VOID VOL
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	STAT-POS	RD MIN	RD MAX	AREA MIN	AREA MAX	AVG PERIF	BURN VOL	AVG SURF	TOTAL SURF	VOID VOL
51	2.2[illegible]E+01	5.0353E-01	1.0997E+00	9.4815E+01	1.4555E+02	8.5294E+01	2.3242E+01	3.8996E+01	1.0908E+03	1.8362E+03
52	2.3317E+01	5.0167E-01	1.0997E+00	9.4815E+01	1.4565E+02	8.5294E+01	2.3242E+01	3.8996E+01	1.1258E+03	1.9048E+03
53	2.37[illegible]E+01	5.0145E-01	1.0997E+00	9.4811E+01	1.4565E+02	8.5294E+01	2.3242E+01	3.8996E+01	1.1608E+03	1.9714E+03
54	2.4213E+01	5.03[illegible]E-01	1.0996E+00	9.4811E+01	1.4565E+02	8.5294E+01	2.3242E+01	3.8996E+01	1.2078E+03	2.0380E+03
55	2.[illegible]E+01	5.0362E-01	1.0975E+00	9.4810E+01	1.4565E+02	8.5294E+01	2.3242E+01	3.8997E+01	1.2408E+03	2.1046E+03
56	2.5145E+01	5.0363E-01	1.0975E+00	9.4804E+01	1.4564E+02	8.5295E+01	2.3242E+01	3.8997E+01	1.2858E+03	2.1712E+03
57	2.5[illegible]E+01	5.0359E-01	1.0975E+00	9.4807E+01	1.4564E+02	8.5295E+01	2.3242E+01	3.8997E+01	1.3248E+03	2.2377E+03
58	2.6[illegible]E+01	5.0357E-01	1.0975E+00	9.4805E+01	1.4554E+02	8.5295E+01	2.3242E+01	3.8997E+01	1.3638E+03	2.3043E+03
59	2.6514E+01	5.0355E-01	1.0975E+00	9.4804E+01	1.4564E+02	8.5295E+01	2.3242E+01	3.8997E+01	1.4028E+03	2.3709E+03
60	2.6515E+01	5.0353E-01	1.0975E+00	9.4802E+01	1.4564E+02	8.5295E+01	2.3242E+01	3.8997E+01	1.4418E+03	2.4375E+03
61	2.7[illegible]E+01	5.0335E-01	1.0975E+00	9.4801E+01	1.4554E+02	8.5296E+01	2.3242E+01	3.8997E+01	1.4808E+03	2.5041E+03
62	2.7572E+01	5.0349E-01	1.0975E+00	9.4759E+01	1.4564E+02	8.5296E+01	2.3242E+01	3.8997E+01	1.5198E+03	2.5707E+03
63	2.8145E+01	5.0347E-01	1.09[illegible]E+00	9.4797E+01	1.4563E+02	8.5296E+01	2.3242E+01	3.8957E+01	1.5588E+03	2.6373E+03
64	2.88[illegible]E+01	5.0345E-01	1.0994E+00	9.4795E+01	1.4563E+02	8.5295E+01	2.3242E+01	3.8997E+01	1.5978E+03	2.7038E+03
65	2.9261E+01	5.034[illegible]E-01	1.0[illegible]E+00	9.4793E+01	1.4563E+02	8.5296E+01	2.3243E+01	3.8997E+01	1.6368E+03	2.7704E+03
66	2.9[illegible]E+01	5.034[illegible]E-01	[illegible]	9.4792E+01	1.4563E+02	8.5297E+01	2.3243E+01	3.8996E+01	1.6758E+03	2.8370E+03
67	[illegible]	5.0[illegible]E-01	1.0[illegible]E+00	9.47[illegible]E+01	1.4563E+02	8.5297E+01	2.3243E+01	3.8998E+01	1.7148E+03	2.9036E+03
68	3.[illegible]E+01	5.03[illegible]E-01	1.0994E+00	9.4793E+01	1.4562E+02	8.5297E+01	2.3243E+01	3.8998E+01	1.7538E+03	2.9702E+03
69	3.1[illegible]E+01	5.033[illegible]E-01	1.09[illegible]E+00	9.[illegible]E+01	1.4562E+02	8.5297E+01	2.3243E+01	3.8995E+01	1.79[illegible]E+03	3.0367E+03
70	[illegible]	5.0[illegible]E-01	1.0[illegible]E+00	9.4[illegible]E+01	1.4562E+02	8.5298E+01	2.3243E+01	3.8993E+01	1.8318E+03	3.1033E+03
71	3.[illegible]E+01	5.0312E-01	1.0[illegible]E+00	9.4[illegible]E+01	1.4447E+02	8.5298E+01	2.3243E+01	3.8993E+01	1.8708E+03	3.1697E+03
72	[illegible]	5.0[illegible]E-01	1.0[illegible]E+00	9.3101E+01	1.4[illegible]E+02	8.5[illegible]E+01	2.3243E+01	3.8996E+01	1.9098E+03	3.2350E+03
73	[illegible]	[illegible]	1.09[illegible]E+00	9.[illegible]E+01	1.4475E+02	8.5[illegible]E+01	2.3243E+01	3.8993E+01	1.9488E+03	3.3017E+03
74	3.3[illegible]E+01	5.0[illegible]E-01	1.0[illegible]E+00	9.[illegible]E+01	1.4451E+02	8.5140E+01	2.3305E+01	3.9202E+01	1.9880E+03	3.3679E+03
75	3.[illegible]E+01	5.0[illegible]E-01	1.0[illegible]E+00	1.0[illegible]E+02	1.4731E+02	7.5600E+01	2.1970E+01	3.0360E+01	2.0240E+03	3.4340E+03
76	[illegible]	[illegible]	[illegible]	1.0967E+02	1.5100E+02	6.9357E+01	1.9670E+01	3.3014E+01	2.0578E+03	3.5026E+03
77	3.47[illegible]E+01	5.03[illegible]E-01	1.0[illegible]E+00	1.1179E+02	1.5274E+02	6.6717E+01	1.8812E+01	3.1564E+01	2.0894E+03	3.5722E+03
78	[illegible]	5.03[illegible]E-01	[illegible]	1.1537E+02	1.5032E+02	6.6717E+01	1.8725E+01	3.1417E+01	2.1208E+03	3.6425E+03
79	[illegible]	[illegible]	[illegible]	1.1[illegible]E+02	1.5101E+02	6.6717E+01	1.8725E+01	3.1417E+01	2.1522E+03	3.7134E+03
80	3.[illegible]E+01	[illegible]	[illegible]	1.0[illegible]E+02	1.5068E+02	6.6717E+01	1.8725E+01	3.1417E+01	2.1836E+03	3.7820E+03
81	[illegible]	[illegible]	[illegible]	1.1[illegible]E+02	1.5517E+02	6.6717E+01	1.8725E+01	3.1417E+01	2.2151E+03	3.8525E+03
82	[illegible]	[illegible]	[illegible]	1.1[illegible]E+02	1.5[illegible]E+02	6.6717E+01	1.8725E+01	3.1417E+01	2.2465E+03	3.9235E+03
83	[illegible]	[illegible]	[illegible]	1.1[illegible]E+02	1.5140E+02	6.6715E+01	1.8725E+01	3.1417E+01	2.2779E+03	3.9937E+03
84	[illegible]	[illegible]	[illegible]	1.[illegible]E+02	1.5113E+02	6.6720E+01	1.8725E+01	3.1417E+01	2.3093E+03	4.0[illegible]E+03
85	3.[illegible]E+01	[illegible]	[illegible]	1.1[illegible]E+02	1.[illegible]E+02	6.3715E+01	1.6725E+01	3.1417E+01	2.3407E+03	4.1334E+03
86	3.[illegible]E+01	[illegible]	[illegible]	1.[illegible]E+02	1.5377E+02	6.6713E+01	1.6725E+01	3.1417E+01	2.3722E+03	4.2030E+03
87	3.[illegible]E+01	[illegible]	[illegible]	1.[illegible]E+02	1.5[illegible]E+02	6.5[illegible]E+01	1.6[illegible]E+01	3.1[illegible]E+01	2.4030E+03	4.2735E+03
88	3.[illegible]E+01	[illegible]	[illegible]	1.1835E+02	1.5975E+02	6.8208E+01	1.6791E+01	3.1529E+01	2.4335E+03	4.3452E+03
89	4.[illegible]E+01	[illegible]	[illegible]	1.1[illegible]E+02	1.5763E+02	6.3974E+01	1.8020E+01	3.0235E+01	2.4055E+03	4.4176E+03
90	4.[illegible]E+01	[illegible]	[illegible]	1.26[illegible]E+02	1.6[illegible]E+02	6.4731E+01	1.7525E+01	2.9422E+01	2.4950E+03	4.4914E+03
91	4.1[illegible]E+01	[illegible]	[illegible]	1.23[illegible]E+02	1.6[illegible]E+02	6.26[illegible]E+01	1.7361E+01	2.9130E+01	2.5241E+03	4.5671E+03
92	4.1[illegible]E+01	5.0[illegible]E-01	[illegible]	1.[illegible]E+02	1.6[illegible]E+02	6.2640E+01	1.7376E+01	2.8052E+01	2.5527E+03	4.6439E+03
93	[illegible]	5.0[illegible]E-01	1.0[illegible]E+00	1.[illegible]E+02	1.[illegible]E+02	5.9[illegible]E+01	1.6605E+01	2.7801E+01	2.5806E+03	4.7240E+03
94	4.[illegible]E+01	5.0[illegible]E-01	[illegible]	1.4174E+02	1.7503E+02	5.5855E+01	1.5581E+01	2.6310E+01	2.6069E+03	4.8053E+03
95	4.25[illegible]E+01	5.0[illegible]E-01	1.0[illegible]E+00	1.4[illegible]E+02	1.[illegible]E+02	5.5653E+01	1.5217E+01	2.5532E+01	2.6326E+03	4.8872E+03
96	4.36[illegible]E+01	5.0[illegible]E-01	1.0[illegible]E+00	1.[illegible]E+02	1.[illegible]E+02	5.4072E+01	1.4774E+01	2.5125E+01	2.6570E+03	4.9726E+03
97	4.38[illegible]E+01	5.0314E-01	1.0[illegible]E+00	1.[illegible]E+02	1.9[illegible]E+02	5.5355E+01	1.4909E+01	2.5015E+01	2.6862E+03	5.0619E+03
98	4.4749E+01	5.0314E-01	1.0991E+00	1.7[illegible]E+02	2.0220E+02	5.1320E+01	1.4534E+01	2.4360E+01	2.7070E+03	5.1537E+03
99	4.[illegible]E+01	5.0[illegible]E-01	1.0[illegible]E+00	1.7[illegible]E+02	4.9448E+02	5.3050E+02	8.0097E+01	1.3439E+02	2.8041E+03	5.3124E+03

[illegible]E+01 1.2266E+02 [illegible]E+03 5.5301E+03

31	[illegible]	[illegible]	[illegible]	4.1337E+02	4.1537E+02	0.	0.	0.	2.9640E+03	5.7299E+03
	[illegible]	[illegible]	.527[illegible]E+03	.5275E+0[illegible]	.1000E+01	.8956E-02				
	[illegible]	[illegible]	.5283E+03	.52[illegible]E+03	.1000E+01	.5276E-02				

4.30 SEC		RHO	C	V	P	A	W	R	MEU	AI	AD	A
1	1	1.284E-03	0.	0.	5.243E+02	1.810E+01	0.	2.524E-01	1.009E+00	4.039E+02	0.	0.
2	1	1.284E-03	2.464E-03	2.230E+01	5.271E+02	2.272E+01	6.530E-02	2.524E-01	1.009E+00	4.039E+02	4.097E+00	4.572E-01
3	1	1.284E-03	[illegible]	5.306E+01	5.271E+02	2.229E+01	1.605E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	9.144E-01
4	1	[illegible]	1.345E-02	1.012E+02	5.271E+02	2.130E+01	2.959E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	1.372E+00
5	1	[illegible]	[illegible]	[illegible]	5.271E+02	[illegible]	4.114E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	1.829E+00
6	1	[illegible]	[illegible]	[illegible]	5.271E+02	[illegible]	5.260E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	2.286E+00
7	1	[illegible]	[illegible]	[illegible]	5.271E+02	2.136E+01	6.422E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	2.743E+00
8	1	[illegible]	[illegible]	[illegible]	5.271E+02	[illegible]	7.576E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	3.200E+00
9	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.731E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	3.658E+00
10	1	[illegible]	[illegible]	[illegible]	5.271E+02	[illegible]	9.885E-01	2.524E-01	1.009E+00	4.039E+02	7.269E+00	4.115E+00
11	1	[illegible]	[illegible]	[illegible]	5.271E+02	2.594E+01	1.104E+00	2.524E-01	1.009E+00	4.039E+02	7.269E+00	4.572E+00
12	1	[illegible]	[illegible]	[illegible]	5.271E+02	2.812E+01	1.219E+00	2.524E-01	1.009E+00	4.039E+02	7.269E+00	5.029E+00
13	1	[illegible]	[illegible]	[illegible]	5.271E+02	2.694E+01	1.335E+00	2.524E-01	1.009E+00	4.039E+02	7.269E+00	5.486E+00
14	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.450E+00	2.524E-01	1.009E+00	4.039E+02	7.269E+00	5.944E+00
15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.566E+00	2.524E-01	1.009E+00	4.039E+02	7.269E+00	6.401E+00
16	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.681E+00	2.524E-01	1.009E+00	4.039E+02	7.269E+00	6.858E+00
17	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.524E-01	1.009E+00	4.039E+02	7.269E+00	7.315E+00
18	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.524E-01	1.009E+00	4.039E+02	7.269E+00	7.772E+00
19	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.524E-01	1.009E+00	4.039E+02	7.269E+00	8.230E+00
20	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.039E+02	7.269E+00	8.687E+00
21	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.524E-01	[illegible]	4.039E+02	7.269E+00	9.144E+00
22	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.524E-01	[illegible]	4.039E+02	[illegible]	[illegible]
23	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.524E-01	[illegible]	[illegible]	[illegible]	[illegible]
24	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
59	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
61	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
64	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
65	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
66	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
67	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	[illegible]	[illegible]	[illegible]
68	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	[illegible]	[illegible]	[illegible]
69	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	[illegible]	[illegible]	[illegible]
70	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	[illegible]	[illegible]	[illegible]
71	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	4.039E+02	[illegible]	[illegible]
72	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	[illegible]	[illegible]	[illegible]
73	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
74	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	[illegible]	[illegible]	[illegible]
75	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.275E+01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
76	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.527E-01	[illegible]	[illegible]	[illegible]	[illegible]
77	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
78	1	[illegible]	[illegible]	1.737E+03	5.255E+02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
79	1	[illegible]	[illegible]	[illegible]	5.237E+02	[illegible]	[illegible]	2.527E-	[illegible]	[illegible]	[illegible]	[illegible]
80	1	[illegible]	2.665E-01	[illegible]	[illegible]	[illegible]	3.533E+01	2.527E-	[illegible]	[illegible]	[illegible]	[illegible]
81	1	[illegible]	[illegible]	[illegible]	5.237E+02	1.485E+02	3.583E+01	2.527E-01	[illegible]	4.039E+02	[illegible]	[illegible]
82	1	[illegible]	[illegible]	1.900E+03	5.237E+02	1.492E+02	3.632E+01	2.527E-01	1.007E+00	4.039E+02	3.123E+01	[illegible]

83	1	[illegible]	[illegible]	2.[illegible]E+03	5.255E+02	1.[illegible]E+02	3.632E+01	2.527E-01	1.007E+00	4.839E+02	3.123E+01	3.749E+01
84	1	1.24[illegible]E-04	2.574E-01	2.012E+03	5.255E+02	1.4[illegible]E+02	3.731E+01	2.527E-01	1.007E+00	4.839E+02	3.123E+01	3.795E+01
85	1	[illegible]	2.5[illegible]E-01	1.[illegible]E+03	5.255E+02	1.[illegible]E+02	3.781E+01	2.527E-[illegible]	1.007E+00	4.839E+02	3.1[illegible]E+01	3.840E+01
86	1	[illegible]	2.551E-01	2.071E+03	5.255E+02	1.[illegible]E+02	3.83[illegible]E+01	2.527E-[illegible]	1.007E+00	4.839E+02	3.123E+01	3.886E+01
87	1	1.240E-04	2.553E-01	2.[illegible]E+03	5.255E+02	1.475E+02	3.68[illegible]E+01	2.527E-01	1.007E+00	4.839E+02	3.120E+01	3.932E+01
88	1	1.24[illegible]E-04	2.572E-01	2.0[illegible]E+03	5.255E+02	1.520E+02	3.924E+01	2.527E-01	1.007E+00	4.839E+02	3.109E+01	3.978E+01
89	1	1.28[illegible]E-04	2.52[illegible]E-01	2.044E+03	5.255E+02	1.518E+02	3.976E+01	2.526E-01	1.007E+00	4.839E+02	3.093E+01	4.023E+01
90	1	1.230E-04	2.572E-01	1.875E+03	5.255E+02	1.552E+02	4.026E+01	2.526E-01	1.007E+00	4.839E+02	3.004E+01	4.069E+01
91	1	1.29[illegible]E-04	2.536E-01	1.941E+03	5.255E+02	1.606E+02	4.072E+01	2.526E-01	1.007E+00	4.839E+02	2.911E+01	4.115E+01
92	1	1.240E-04	2.514E-01	1.964E+03	5.255E+02	1.637E+02	4.117E+01	2.526E-01	1.007E+00	4.839E+02	2.830E+01	4.161E+01
93	1	1.24[illegible]E-04	2.473E-01	1.853E+03	5.255E+02	1.754E+02	4.161E+01	2.527E-01	1.007E+00	4.839E+02	2.750E+01	4.206E+01
94	1	1.2[illegible]9E-04	2.474E-01	1.933E+03	5.255E+02	1.694E+02	4.204E+01	2.526E-01	1.007E+00	4.839E+02	2.710E+01	4.252E+01
95	1	1.240E-04	2.334E-01	1.906E+03	5.255E+02	1.777E+02	4.245E+01	2.526E-01	1.007E+00	4.839E+02	2.651E+01	4.298E+01
96	1	1.28[illegible]E-04	2.133E-01	1.749E+03	5.255E+02	1.861E+02	4.28[illegible]E+01	2.527E-01	1.007E+00	4.839E+02	2.595E+01	4.343E+01
97	1	1.29[illegible]E-04	2.22[illegible]E-01	1.73[illegible]E+03	5.255E+02	1.943E+02	4.325E+01	2.527E-01	1.007E+00	4.839E+02	2.500E+01	4.389E+01
98	1	1.24[illegible]E-04	2.013E-01	1.725E+03	5.255E+02	1.975E+02	4.364E+01	2.527E-01	1.0[illegible]E+00	4.839E+02	2.435E+01	4.435E+01
99	1	1.231E-04	1.724E-01	8.324E+02	5.259E+02	4.453E+02	4.397E+01	2.527E-01	1.007E+00	4.839E+02	1.342E+02	4.481E+01
100	1	1.241E-04	1.354E-01	9.230E+02	5.25[illegible]E+02	4.556E+02	4.434E+01	2.527E-01	1.0[illegible]E+00	4.839E+02	1.430E+02	4.526E+01
101	1	1.241E-04	1.15[illegible]E-01	4.025E+02	5.259E+02	4.18[illegible]E+02	4.837E+01	2.52[illegible]E-01	1.0[illegible]E+00	4.839E+02	2.000E+01	4.572E+01

		T	F	FJ	ISP	PT	PE	VE	ABI	AG	APO
102	0	4.030E+00	1.4[illegible]E+04	1.433E-04	2.452E+02	5.233E+02	1.571E+00	1.091E+05	0.	3.347E+03	1.445E+01
		I P	I PO	I WI	I [illegible]	I FD					
		1.574E+01	1.570E+03	1.151E-01	1.435E+02	4.253E+04					

26.00 SEC	PHI	C	V	P	A	W	H	MEJ	AI	AB	X
1	1	[illegible]	1.	[illegible]	5.534E+02	1.810E+01	0.	2.557E-01	6.517E+00	3.145E+03	0.	0.
2	1	[illegible]	[illegible]	[illegible]	[illegible]	1.125E+01	-2.170E-05	2.557E-01	6.514E+00	[illegible]	0.	[illegible]
3	1	[illegible]	[illegible]	[illegible]	5.447E+02	1.356E+02	-7.197E-05	2.557E-01	6.515E+00	3.172E+03	0.	[illegible]
4	1	[illegible]	[illegible]	[illegible]	[illegible]	1.830E+02	1.582E-02	2.557E-01	6.515E+00	3.172E+03	1.057E+00	1.372E+00

83	1	1.326E-0?	[illegible]	[illegible]	5.4??E+02	5.38?E+02	4.52?E+01	2.557E-01	6.514E+00	3.1?4E+03	3.85?E+01	3.??E+01
84	1	1.35?E-0?	4.??E-02	6.078E+02	5.478E+02	5.350E+02	4.58?E+01	2.557E-01	6.514E+00	3.17?E+03	3.854E+01	3.795E+01
85	1	1.35?E-0?	4.??E-02	[illegible]	5.47?E+02	5.640E+02	4.6??E+01	2.557E-01	6.514E+00	3.172E+03	3.854E+01	3.8??E+01
86	1	1.35?E-0?	4.??E-02	[illegible]	5.47?E+02	5.5??E+02	4.7??E+01	2.556E-01	6.514E+00	3.172E+03	3.854E+01	3.880E+01
87	1	1.35?E-0?	[illegible]	[illegible]	5.47?E+02	5.907E+02	4.784E+01	2.556E-01	6.514E+00	3.172E+03	4.72?E+01	3.9??E+01
88	1	1.35?E-0?	7.??E-02	[illegible]	5.47?E+02	6.725E+02	4.917E+01	2.557E-01	6.514E+00	3.172E+03	8.253E+01	3.978E+01
89	1	1.35?E-0?	5.7??E-02	[illegible]	5.47?E+02	7.5??E+02	5.081E+01	2.557E-01	6.514E+00	3.172E+03	1.029E+02	4.02?E+01
90	1	1.35?E-0?	6.635E-02	4.910E+02	5.47?E+02	7.???E+02	5.195E+01	2.557E-01	6.514E+00	3.172E+03	7.917E+01	4.0??E+01
91	1	1.35?E-0?	5.855E-02	5.080E+02	5.47?E+02	7.621E+02	5.235E+01	2.557E-01	6.514E+00	3.172E+03	2.580E+01	4.113E+01
92	1	1.35?E-0?	7.113E-02	5.375E+02	5.47?E+02	7.390E+02	5.243E+01	2.557E-01	6.514E+00	3.172E+03	3.148E+00	4.181E+01
93	1	1.352E-0?	7.553E-02	5.382E+02	5.47?E+02	7.031E+02	5.240E+01	2.557E-01	6.514E+00	3.2?5E+03	0.	4.2??E+01
94	1	1.35?E-0?	7.911E-02	5.777E+02	5.47?E+02	6.7??E+02	5.240E+01	2.556E-01	6.514E+00	3.250E+03	0.	4.252E+01
95	1	1.35?E-0?	8.214E-02	[illegible]	5.47?E+02	6.379E+02	5.24?E+01	2.556E-01	6.514E+00	3.2?5E+03	0.	4.290E+01
96	1	1.35?E-0?	9.0??E-02	[illegible]	5.47?E+02	6.0??E+02	5.243E+01	2.556E-01	6.514E+00	3.340E+03	0.	4.343E+01
97	1	1.35?E-0?	9.1??E-02	[illegible]	5.47?E+02	5.655E+02	5.240E+01	2.556E-01	6.514E+00	3.379E+03	0.	4.38?E+01
98	1	1.35?E-0?	9.151E-02	7.2??E+02	5.47?E+02	5.315E+02	5.24?E+01	2.556E-01	6.514E+00	3.417E+03	0.	4.4??E+01
99	1	1.35?E-0?	1.06?E-01	7.627E+02	5.47?E+02	4.965E+02	5.240E+01	2.556E-01	6.514E+00	3.454E+03	0.	4.461E+01
100	1	1.352E-0?	1.135E-01	8.535E+02	5.478E+02	4.556E+02	5.240E+01	2.556E-01	6.514E+00	3.489E+03	0.	4.52?E+01
101	1	1.34?E-0?	1.252E-01	9.203E+02	5.477E+02	4.18?E+02	5.240E+01	2.556E-01	6.514E+00	3.523E+03	0.	4.572E+01

		T	F	FD	ISP	PT	PE	VE	Ae1	Ae	Aim
132	0	2.600E+01	1.344E+04	1.540E+04	2.9??E+02	5.511E+02	1.733E+00	1.061E+05	0.	3.205E+03	1.510E+01
		I P	I FO	I ml	I w	I FU					
		1.285E+04	1.284E+04	5.340E+00	1.231E+03	3.528E+05					

	STAT-DCC	[illegible] MIN	[illegible] MAX	AREA MIN	AREA MAX	AVG PERIF	BURN VOL	AVG SURF	TOTAL SURF	VOID VOL
1	0.	[illegible]	[illegible]	1.8090E+01	1.0070E+01	0.	0.	0.	0.	0.
2	6.5720E-01	[illegible]	[illegible]	7.1267E+01	7.1267E+01	0.	0.	0.	0.	2.0924E+01
3	9.1490E-01	[illegible]	[illegible]	1.3555E+02	1.3565E+02	0.	0.	0.	0.	6.7720E+01
4	1.2716E+00	[illegible]	[illegible]	1.8290E+02	1.8250E+02	0.	0.	0.	0.	1.4030E+02
5	[illegible]	[illegible]	[illegible]	2.1509E+02	2.1165E+02	2.6526E+01	3.6866E+00	6.5211E+00	6.5211E+00	2.3360E+02
6	[illegible]	[illegible]	[illegible]	2.2122E+02	2.5111E+02	4.5651E+01	1.0031E+01	1.7671E+01	2.4392E+01	3.4301E+02
7	[illegible]	[illegible]	[illegible]	2.1701E+02	[illegible]	4.9651E+01	1.3329E+01	2.2730E+01	4.7193E+01	4.6039E+02
8	[illegible]	[illegible]	[illegible]	2.1759E+02	2.4758E+02	4.9651E+01	1.3329E+01	2.2730E+01	6.9793E+01	5.7330E+02
9	[illegible]	[illegible]	[illegible]	2.2223E+02	2.5182E+02	4.9651E+01	1.3329E+01	2.2700E+01	9.2493E+01	6.8752E+02
10	[illegible]	[illegible]	[illegible]	2.2316E+02	2.5157E+02	4.9651E+01	1.3329E+01	2.2700E+01	1.1519E+02	8.0305E+02
11	[illegible]	[illegible]	[illegible]	2.2156E+02	2.5118E+02	4.9651E+01	1.3329E+01	2.2700E+01	1.3789E+02	9.1644E+02
12	[illegible]	[illegible]	[illegible]	2.2377E+02	2.5138E+02	4.9651E+01	1.3329E+01	2.2700E+01	1.6059E+02	1.0330E+03
13	[illegible]	[illegible]	[illegible]	2.2259E+02	2.5214E+02	4.9651E+01	1.3329E+01	2.2700E+01	1.8329E+02	1.1493E+03
14	[illegible]	[illegible]	[illegible]	2.1575E+02	2.4534E+02	4.9651E+01	1.3329E+01	2.2700E+01	2.0599E+02	1.2640E+03
15	[illegible]	[illegible]	[illegible]	2.1549E+02	2.4035E+02	4.9651E+01	1.3329E+01	2.2700E+01	2.2870E+02	1.3772E+03
16	[illegible]	[illegible]	[illegible]	2.2304E+02	[illegible]	5.6652E+01	1.5001E+01	2.6170E+01	2.5487E+02	1.4926E+03
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.6000E+01	2.0543E+01	3.4630E+01	2.8951E+02	1.6170E+03
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3544E+01	3.9512E+01	3.2902E+02	1.7560E+03
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3239E+01	3.6971E+01	3.6001E+02	1.9017E+03
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.6032E+01	2.2211E+01	3.7271E+01	4.0529E+02	2.0012E+03
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.3836E+01	2.2145E+01	3.7110E+01	4.4265E+02	2.2317E+03
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.0434E+01	[illegible]	2.4138E+03
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.9551E+01	2.3356E+01	3.7163E+01	5.2209E+02	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5814E+01	2.2359E+01	3.7575E+01	5.5901E+02	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.7513E+01	2.5015E+01	3.7625E+01	5.9924E+02	3.0110E+03
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3606E+01	3.7142E+01	6.3695E+02	3.2290E+03
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3775E+01	3.7677E+01	6.7062E+02	3.4500E+03
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.2775E+01	3.8551E+01	7.1537E+02	3.7011E+03
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3753E+01	3.9217E+01	7.5342E+02	3.9411E+03
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3651E+01	4.0013E+01	7.9345E+02	4.1517E+03
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.4465E+01	4.1094E+01	8.3350E+02	4.4430E+03
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5113E+01	2.3015E+01	3.9653E+01	8.7357E+02	4.7055E+03
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.3818E+01	2.3016E+01	3.8617E+01	9.1421E+02	4.9730E+03
34	[illegible]	[illegible]	[illegible]	[illegible]	5.8991E+02	9.2124E+01	2.4109E+01	4.0452E+01	9.5460E+02	5.2390E+03
35	[illegible]	[illegible]	[illegible]	[illegible]	5.5670E+02	9.1094E+01	2.5101E+01	4.2115E+01	9.9677E+02	5.5109E+03
36	[illegible]	[illegible]	[illegible]	5.5035E+02	[illegible]	8.7003E+01	2.4373E+01	4.0855E+01	1.0377E+03	5.7850E+03
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5013E+01	2.3763E+01	3.9671E+01	1.0779E+03	6.0814E+03
38	[illegible]	[illegible]	[illegible]	[illegible]	6.0994E+02	8.6013E+01	2.3520E+01	3.9463E+01	1.1170E+03	6.3395E+03
39	[illegible]	[illegible]	[illegible]	[illegible]	6.1212E+02	8.5706E+01	2.3396E+01	3.9253E+01	1.1563E+03	6.6189E+03
40	[illegible]	[illegible]	[illegible]	[illegible]	6.1324E+02	8.5591E+01	2.3380E+01	3.9159E+01	1.1954E+03	6.8990E+03
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5613E+01	2.3327E+01	3.9140E+01	1.2346E+03	7.1793E+03
42	[illegible]	[illegible]	[illegible]	[illegible]	6.1267E+02	8.5637E+01	2.3357E+01	3.9160E+01	1.2737E+03	7.4595E+03
43	[illegible]	[illegible]	[illegible]	[illegible]	6.1267E+02	8.5637E+01	2.3382E+01	3.9231E+01	1.3130E+03	7.7396E+03
44	[illegible]	[illegible]	[illegible]	5.6152E+02	6.1267E+02	8.5637E+01	2.3382E+01	3.9231E+01	1.3522E+03	8.0197E+03
45	[illegible]	[illegible]	[illegible]	5.6152E+02	6.1267E+02	8.5637E+01	2.3382E+01	3.9231E+01	1.3914E+03	8.2999E+03
46	[illegible]	[illegible]	[illegible]	5.6152E+02	6.1266E+02	8.5608E+01	2.3382E+01	3.9231E+01	1.4307E+03	8.5800E+03
47	[illegible]	[illegible]	[illegible]	5.6152E+02	6.1266E+02	8.5608E+01	2.3382E+01	3.9231E+01	1.4699E+03	8.8601E+03
48	[illegible]	[illegible]	[illegible]	5.6152E+02	6.1266E+02	8.5608E+01	2.3382E+01	3.9232E+01	1.5091E+03	9.1402E+03
49	[illegible]	[illegible]	[illegible]	5.6151E+02	6.1225E+02	8.5809E+01	2.3382E+01	3.9232E+01	1.5484E+03	9.4203E+03
50	[illegible]	6.5161E+00	7.1121E+00	5.6131E+02	[illegible]	8.5809E+01	2.3382E+01	3.9232E+01	1.5876E+03	9.7004E+03

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOTAL SORT	VOID VOL
51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
59	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
61	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
66	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.2135E+03	1.4102E+04
67	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3384E+01	3.9235E+01	2.2546E+03	1.4462E+04
68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5617E+01	2.3394E+01	3.9235E+01	2.2938E+03	1.4742E+04
69	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5614E+01	2.3385E+01	3.9236E+01	2.3330E+03	1.5022E+04
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3385E+01	3.9236E+01	2.3723E+03	1.5302E+04
71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3385E+01	3.9236E+01	2.4115E+03	1.5582E+04
72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5620E+01	2.3385E+01	3.9237E+01	2.4507E+03	1.5862E+04
73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3385E+01	3.9237E+01	[illegible]	1.6141E+04
74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3385E+01	3.9237E+01	[illegible]	[illegible]
75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5821E+01	2.3386E+01	3.9237E+01	2.5683E+03	1.6700E+04
76	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5621E+01	2.3386E+01	3.9238E+01	2.6077E+03	1.6979E+04
77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5622E+01	[illegible]	3.9238E+01	2.6469E+03	1.7258E+04
78	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5622E+01	2.3386E+01	3.9238E+01	2.6862E+03	1.7539E+04
79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5623E+01	2.3386E+01	3.9238E+01	2.7254E+03	1.7815E+04
80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.7646E+03	[illegible]
81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5623E+01	2.3386E+01	3.9238E+01	2.8039E+03	1.8379E+04
82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5624E+01	2.3386E+01	3.9238E+01	2.8431E+03	1.8660E+04
83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5625E+01	2.3386E+01	3.9239E+01	2.8824E+03	1.8940E+04
84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5625E+01	2.3387E+01	3.9239E+01	2.9216E+03	1.9219E+04
85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5825E+01	2.3387E+01	3.9239E+01	2.9608E+03	1.9500E+04
86	[illegible]	[illegible]	[illegible]	5.5905E+02	6.2103E+02	1.0299E+02	2.5862E+01	4.3352E+01	3.0042E+03	1.9783E+04
87	[illegible]	[illegible]	[illegible]	[illegible]	7.2366E+02	2.5540E+02	4.8955E+01	8.2156E+01	[illegible]	[illegible]
88	[illegible]	[illegible]	[illegible]	[illegible]	7.4329E+02	1.8620E+02	6.0165E+01	1.0095E+02	3.1473E+03	2.0437E+04
89	[illegible]	[illegible]	[illegible]	7.5721E+02	[illegible]	9.4974E+01	[illegible]	6.6277E+01	[illegible]	[illegible]
90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	1.2940E+01	2.1711E+01	3.2735E+03	2.1171E+04
91	[illegible]	[illegible]	[illegible]	[illegible]	7.6235E+02	0.	0.	0.	[illegible]	[illegible]
92	[illegible]	[illegible]	[illegible]	7.3457E+02	[illegible]	0.	0.	0.	[illegible]	[illegible]
93	[illegible]	[illegible]	[illegible]	7.0307E+02	[illegible]	0.	0.	0.	[illegible]	[illegible]
94	[illegible]	[illegible]	[illegible]	6.7079E+02	[illegible]	0.	0.	0.	[illegible]	[illegible]
95	[illegible]	[illegible]	7.1100E+00	6.3783E+02	[illegible]	0.	0.	0.	[illegible]	[illegible]
96	[illegible]	[illegible]	7.1101E+00	6.0476E+02	6.0478E+02	0.	0.	0.	[illegible]	[illegible]
97	[illegible]	[illegible]	[illegible]	5.6991E+02	5.6991E+02	0.	0.	0.	[illegible]	[illegible]
98	[illegible]	[illegible]	7.1102E+00	5.3188E+02	5.3188E+02	0.	0.	0.	[illegible]	[illegible]
99	4.4808E+01	[illegible]	7.1103E+00	4.9444E+02	4.9448E+02	0.	0.	0.	[illegible]	[illegible]

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00 4.5283E+01 6.5144+00 7.1104E+00 4.5563E+02 4.5563E+02 0. 0. 0. 3.2733E+03 2.4006E+04
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84	1	1.475E-05	7.673E-04	1.542E+02	6.231E+00	9.194E+02	6.874E-01	2.079E-02	1.198E+01	5.991E+03	0.	3.893E+01
85	1	1.475E-05	7.571E-04	[illegible]	6.231E+00	[illegible]	6.904E-01	2.079E-02	1.198E+01	6.090E+03	0.	3.849E+01
86	1	1.475E-05	7.471E-04	[illegible]	6.231E+00	[illegible]	6.934E-01	2.079E-02	1.198E+01	6.080E+03	0.	3.880E+01
87	1	1.475E-05	[illegible]	[illegible]	6.231E+00	[illegible]	6.962E-01	2.079E-02	1.198E+01	6.130E+03	0.	3.932E+01
88	1	1.475E-05	[illegible]	[illegible]	6.231E+00	6.378E+02	6.996E-01	2.079E-02	1.198E+01	6.183E+03	0.	3.978E+01
89	1	1.475E-05	[illegible]	[illegible]	6.231E+00	[illegible]	7.017E-01	2.079E-02	1.198E+01	6.230E+03	0.	4.023E+01
90	1	1.475E-05	[illegible]	[illegible]	6.230E+00	7.058E+02	7.043E-01	2.079E-02	1.198E+01	6.275E+03	0.	4.069E+01
91	1	1.475E-05	[illegible]	[illegible]	6.230E+00	7.062E+02	7.069E-01	2.079E-02	1.198E+01	6.321E+03	0.	4.115E+01
92	1	1.475E-05	[illegible]	[illegible]	6.230E+00	7.196E+02	7.094E-01	2.079E-02	1.198E+01	6.365E+03	0.	4.161E+01
93	1	1.475E-05	[illegible]	[illegible]	6.230E+00	7.211E+02	7.117E-01	2.079E-02	1.198E+01	6.409E+03	0.	4.206E+01
94	1	1.475E-05	[illegible]	[illegible]	6.230E+00	[illegible]	7.140E-01	2.079E-02	1.198E+01	6.451E+03	0.	4.252E+01
95	1	1.475E-05	[illegible]	5.580E+02	6.230E+00	6.879E+02	7.161E-01	2.079E-02	1.198E+01	6.492E+03	0.	4.298E+01
96	1	1.475E-05	[illegible]	[illegible]	6.230E+00	[illegible]	7.132E-01	2.079E-02	1.195E+01	6.533E+03	0.	4.343E+01
97	1	1.475E-05	[illegible]	[illegible]	6.230E+00	5.697E+02	7.201E-01	2.079E-02	1.198E+01	6.572E+03	0.	4.389E+01
98	1	1.475E-05	1.553E-03	7.130E+02	6.230E+00	5.315E+02	7.219E-01	2.079E-02	1.198E+01	6.610E+03	0.	4.435E+01
99	1	1.475E-05	1.643E-03	7.636E+02	6.231E+00	4.945E+02	7.236E-01	2.079E-02	1.198E+01	6.647E+03	0.	4.481E+01
100	1	1.675E-05	1.552E-03	9.426E+02	6.249E+00	4.550E+02	7.252E-01	2.079E-02	1.198E+01	6.682E+03	0.	4.526E+01
101	1	1.675E-05	1.737E-03	9.262E+02	6.249E+00	4.164E+02	7.266E-01	2.079E-02	1.198E+01	6.716E+03	0.	4.572E+01

		T	S	FU	ISP	PT	PL	VE	Abl	Ab	APP
102	4	5.000E+01	1.932E+02	1.572E+02	2.113E+02	6.237E+03	2.056E-02	9.779E+04	0.	3.417E+02	1.500E+01

P	Fo	Fd	W	FU	
2.631E+04	2.630E+04	2.031E+01	2.231E+03	6.768E+05	
.6245E+04	.1366E+02	.2300E+01	.2030E+01	.1000E+01	-.5104E+00
.4725E+04	.1366E+02	.2C00E+01	.2085E+01	.1000E+01	-.2472E+00
.4517E+04	.1366E+02	.2032E+01	.2033E+01	.1000E+01	-.1224E-01
.4517E+04	.1366E+02	.2000E+01	.2072E+01	.1000E+01	-.4291E-01
.4512E+04	.1366E+02	.2300E+01	.2010E+01	.1000E+01	-.7593E-02
.4012E+04	.1366E+02	.2000E+01	.2079E+01	.1000E+01	-.2209E-02

[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
100	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.	[illegible]
101	1	6.157E-07	5.671E-04	9.072E+02	2.385E+00	[illegible]	2.375E-01	2.985E-02	1.203E+01	6.712E+03	0.	9.372E+01

		T	F	FD	ISP	PT	PE	VE	ABI	AB	APO
102	4	5.270E+01	6.319E+01	2.322E+01	9.779E+01	2.000E+00	6.854E-03	9.779E+04	0.	1.137E+02	1.566E+01
		TP	PO	W	H	FO					
		2.432E+04	2.431E+04	2.192E+01	2.324E+03	6.770E+05					

SUMMARY OUTPUT FROM BALLISTICS MODULE

I	TIME	PC	L*	R*	D(R*)/DT	W DOT	ETA C*
1	2.0000	520.84	272.46	2.1416	.16337E-02	1.4786	.97363
2	4.0000	528.27	378.26	2.1449	.16337E-02	1.5034	.97370
3	6.0000	518.65	481.29	2.1493	.21867E-02	1.4809	.97365
4	8.0000	512.12	552.47	2.1538	.22562E-02	1.4677	.97355
5	10.000	497.54	680.27	2.1581	.21777E-02	1.4310	.97339
6	12.000	[illegible]	775.52	2.1624	.21365E-02	1.4047	.97324
7	14.000	[illegible]	870.53	2.1667	.21323E-02	1.4110	.97323
8	16.000	[illegible]	959.15	2.1710	.21648E-02	1.4742	.97345
9	18.000	506.82	1067.2	2.1752	.21239E-02	1.4773	.97347
10	20.000	[illegible]	1165.9	2.1796	.21553E-02	1.4988	.97351
11	22.000	[illegible]	1267.0	2.1839	.21520E-02	1.5440	.97365
12	24.000	541.58	1370.6	2.1882	.21842E-02	1.5947	.97381
13	26.000	551.16	1475.6	2.1927	.22161E-02	1.6285	.9739[illegible]
14	28.000	[illegible]	1587.2	2.1971	.22116E-02	1.6735	.97405
15	30.000	[illegible]	1691.9	2.2016	.22433E-02	1.7155	.97417
16	32.000	[illegible]	1801.9	2.2060	.22388E-02	1.7431	.97423
17	34.000	[illegible]	1912.[illegible]	2.2105	.22342E-02	1.7617	.97428
18	36.000	[illegible]	2022.6	2.2150	.22297E-02	1.7775	.97431
19	38.000	591.45	2133.6	2.2194	.22252E-02	1.7848	.97432
20	40.000	592.64	2243.0	2.2237	.21492E-02	1.7950	.97433
21	42.000	[illegible]	2351.1	2.2280	.21451E-02	1.7751	.97428
22	44.000	536.59	2449.5	2.2319	.19270E-02	1.6349	.97377
23	46.000	187.57	2481.3	2.2327	.42778E-03	.56626	.96097
24	48.000	54.013	2490.9	2.2329	.71281E-04	.17100	.87181
25	50.000	[illegible]	2491.9	2.2329	0.	.22583E-01	.75234
26	52.000	[illegible]	2492.3	2.2329	0.	.73805E-02	.77771

FROM BALLISTICS CALCULATIONS THE FOLLOWING ARE THE AVERAGE,MAX, AND MIN VALUES OF THE QUANTITIES INDICATED

QUANTITY	AVERAGE	MAXIMUM	MINIMUM
PC PSIA	833.40	592.[illegible]	2.0746
LO IN	1193.1	2492.3	272.46
DO IN	2.[illegible]845	2.2329	2.1416
ETA [illegible]	.97353	.97613	.76234
R DOT S /SEC	1.5727	1.7950	.73805E-02

VALUES AT TIMES GREATER THAN 46.000 HAVE BEEN EXCLUDED FROM THE AVERAGE CALCULATION

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************************************************************************************************************
              TWO DIMENSIONAL - TWO PHASE FLOW LOSS MODEL (TD2P)

                   EXTENDED DELTA VALIDATION CASE

               INPUT CONDITIONS
     PC=        533.8C6            TSC=        6050.650
     LSTAR=     1393.130           ITOT=              3
     RHGP=     .6116E-04           CAPN=         .67175
     RPWGT=        .38687          WT FRAC=      .27791

B(I)=   .1146216E+01 F(I)=   .1753956E+01 CPC =   .1671716E+05   G =   .1178694E+01RCAP =   .2536372E+06
CPS =   .8240560E+04 MPS =   .3465926E+04 MOL =   .4695376E+08 MPO =  .6296227E+08  PR =   .4569390E+00
RHOGO=  .1412162E+00   R =   .1159307E+01  US =   .1163379E+01 GSB =  .1145943E+01

AT EXPANSION AREA RATIO =   30.836 ISP(IDOL)=   314.362 UE(IDOL)=  9506.8041

       MEAN PARTICLE DIAMETER(MICRONS)=  2.836?
          PARTICLE SIZE DISTRIBUTION

   GROUP    R(FT)        D(MICRONS)       WPWT
     1    .2517E-05      1.5345          .33333
     2    .4670E-05      2.8467          .33333
     3    .8675E-05      5.2881          .33333
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GAS-PARTICLE FLOW

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K BAR=1.1452143      WDG=   34.2108            EQUILIBRIUM CONDITIONS.

ONE DIMENSIONAL FLOW
Z0=  -4.1888     MAX= -2.39975    STEP SIZE=  .002300    U0=  355.973    TPIO= 6046.260    A0=    .5991

Z= -2.39975     A/AT=  1.06986          UG= 1130.332      UP(I)      TP(I)         K(I)         L(I)        I=1...  3
  1096.655     6009.056        .96844        .97276     1039.797    6016.737      .91990       .93350
   961.266     6013.333        .85038        .87279

ITERATION NUMBER  3             I        VAR(I)              F(I)            TH=  0.0000
                                1    -.1495286E+00       .9363692E-01
                                2     .1000000E+01      -.1927335E-07
                                3     .5068323E+00      -.1208892E-06
                                4     .3-38693E 00      -.2378649E-06
                                5    -.1621522E+01      -.7838509E-06

ITERATION NUMBER  3             I        VAR(I)              F(I)            TH=-34.0000
                                1     .3613691E+00       .3219052E-07
                                2     .3513023E+00       .7878885E-07
                                3     .3108695E+00       .1647614E-06
                                4     .2111293E+00      0.
                                5     .6759579E+00      0.

ITERATION NUMBER  3             I        VAR(I)              F(I)            TH=-22.6667
                                1     .1514937E+00      -.1274108E-05
                                2     .5455868E+00      -.6331116E-06
                                3     .3814601E+00       .3791290E-05
                                4     .4175334E+00      0.
                                5     .7626481E+00      0.

ITERATION NUMBER  3             I        VAR(I)              F(I)            TH=-11.3333
                                1    -.4402451E-01      -.2832759E-07
                                2     .7781565E+00      -.3318549E-06
                                3     .4250936F+00       .1212021E-05
                                4     .6313477E+00      0.
                                5    -.4701676E+00      0.

ITERATION NUMBER  4             I        VAR(I)              F(I)            TH=  0.0000
                                1    -.3127837E+00       .1315639E-06
                                2     .1084338E+01      -.2461773E-06
                                3     .5290986E+00      -.4915158E-06
                                4     .2346874E+00      -.1002463E-05
                                5    -.1350321E+01      -.2978857E-05

ITERATION NUMBER  4             I        VAR(I)              F(I)            TH=  4.5000
                                1    -.4014379E+00       .3704766E-07
                                2     .1213413E+01      -.1066335E-06
                                3     .5407105E+00      -.1672728E-06
                                4     .1017874E+00      -.3825359E-06
                                5    -.1010577E+01      -.1095578E-05

ITERATION NUMBER  4             I        VAR(I)              F(I)            TH=  9.0000
                                1    -.4834386E+00       .2285384E-07
                                2     .1338347E+01      -.1226946E-06
                                3     .5330849E+00      -.1400617E-06
                                4     .3967679E-02      -.3183389E-06
                                5    -.7631818E+00      -.8174301E-06
K BAR=1.1434663
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ITERATION NUMBER  2              I      VAR(I)           F(I)            TH=  9.0000
                                 1   -.4431793E+00    -.1107110E-06
                                 2    .1338532E+01     .1264146E-06
                                 3    .5336393E+00     .6144357E-06
                                 4    .4497715E-02     .1656492E-05
                                 5   -.7434064E+00     .5697987E-05

   WDG=     36.5967    WDP(I)=    4.4371      4.4371      4.4371

ONE DIMENSIONAL FLOW
ZA=  -4.2087    MAR= -2.39975    STEP SIZE=  .002000    UO=  355.973    TPIO= 6046.260    AO=    .6057

Z= -9.39975    A/AT=  1.96908      UG= 1144.103     UP(I)      TP(I)        K(I)        L(I)       I=1...  3
   1107.511    6008.065      .96802       .97403   1051.796    6009.793      .91932      .93451
    971.861    6012.468      .84945       .87333

ITERATION NUMBER  3              I      VAR(I)           F(I)            TH=  0.0600
                                 1   -.1694824E+00     .9365594E-01
                                 2    .1000000E+01    -.2019657E-07
                                 3    .5071220E+00    -.1263609E-06
                                 4    .3431871E+00    -.2485549E-06
                                 5   -.1620322E+01    -.8192841E-06

ITERATION NUMBER  1              I      VAR(I)           F(I)            TH=-34.0000
                                 1    .3601041E+00    -.2467248E-05
                                 2    .3505509E+00     .3675187E-05
                                 3    .3163974E+00    -.2332865E-05
                                 4    .2112711E+00     0.
                                 5    .6664540E+00     0.

ITERATION NUMBER  7              I      VAR(I)           F(I)            TH=-22.6667
                                 1    .1497340E+00    -.1278857E-05
                                 2    .5452931E+00    -.6517419E-06
                                 3    .3826730E+00     .3841785E-05
                                 4    .4149432E+00     0.
                                 5    .7498122E+00     0.

ITERATION NUMBER  7              I      VAR(I)           F(I)            TH=-11.3333
                                 1   -.4466674E-01    -.3608095E-07
                                 2    .7781610E+00    -.3299304E-06
                                 3    .4262176E+00     .1223546E-05
                                 4    .6285918E+00     0.
                                 5   -.4556664E+00     0.

ITERATION NUMBER  9              I      VAR(I)           F(I)            TH=  0.0000
                                 1   -.3124921E+00     .1307174E-06
                                 2    .1096367E+01    -.2446315E-06
                                 3    .5294440E+00    -.4813147E-06
                                 4    .2350043E+00    -.9958931E-06
                                 5   -.1349436E+01    -.2960550E-05

ITERATION NUMBER  4              I      VAR(I)           F(I)            TH=  4.5000
                                 1   -.4012630E+00     .3658636E-07
                                 2    .1213701E+01    -.1054178E-06
                                 3    .5411559E+00    -.1652119E-06
                                 4    .1022142E+00    -.3778556E-06
                                 5   -.1019341E+01    -.1072323E-05

ITERATION NUMBER  4              I      VAR(I)           F(I)            TH=  9.0000
                                 1   -.4431793E+00     .2240810E-07
                                 2    .1338532E+01    -.1211854E-06
                                 3    .5336394E+00    -.1376069E-06
                                 4    .4497742E-02    -.3127240E-06
                                 5   -.7434060E+00    -.8013692E-06

K BAR=1.1474588
```

```
ITERATION NUMBER  1          I      VAR(I)          F(I)          TH=  9.0000
                             1   -.4831782E+00   -.3852495E-07
                             2    .1338533E+01    .4180272E-07
                             3    .5336417E+00    .2198699E-06
                             4    .4500026E-02    .6096906E-06
                             5   -.7634072E+00    .2109418E-05

   WPG=    36.5491    WPH(I)=    4.4374    4.4374    4.4374

ONE DIMENSIONAL FLOW
ZO=  -4.2089    MAX= -2.39975    STEP SIZE=  .002000    UO=  355.973    TPIO= 6046.260    AO=   .6057

Z= -2.39975    A/AT=  1.96968        UG= 1[illegible]4.191    UP(I)     TP(I)       K(I)      L(I)     I=1...  3
   1107.597    6008.059      .96801     .97429    1051.872   6009.787    .91932    .93476
    971.920    6012.462      .84945     .87356

ITERATION NUMBER  3          I      VAR(I)          F(I)          TH=  0.0000
                             1   -.1494826E+00    .9365602E-01
                             2    .1000000E+01   -.2020057E-07
                             3    .5771224E+00   -.1263845E-06
                             4    .3441884E+00   -.2486012E-06
                             5   -.1620317E+01   -.8194373E-06

ITERATION NUMBER  1          I      VAR(I)          F(I)          TH=-34.0000
                             1    .3601417E+00    .1200434E-07
                             2    .3505472E+00   -.2164247E-07
                             3    .3103589E+00    .1711984E-07
                             4    .2112974E+00   0.
                             5    .6682951E+00   0.

ITERATION NUMBER  [illegible]          I      VAR(I)          F(I)          TH=-22.6667
                             1    .1497269E+00   -.1280533E-05
                             2    .5452901E+00   -.6522334E-06
                             3    .3826737E+00    .3845327E-05
                             4    .4149361E+00   0.
                             5    .7497369E+00   0.

ITERATION NUMBER  3          I      VAR(I)          F(I)          TH=-11.3333
                             1   -.44[illegible]223E-01   -.3616500E-07
                             2    .778[illegible]12E+00   -.3299592E-06
                             3    .[illegible]3E+00    .1223845E-05
                             4    .6265679[illegible]+00   0.
                             5   -.4555498E+00   0.

ITERATION NUMBER  [illegible]          I      VAR(I)          F(I)          TH=  0.0000
                             1   -.3126917E+00    .1307153E-06
                             2    .1084367E+01   -.2446273E-06
                             3    .5294454E+00   -.4885068E-06
                             4    .2350057E+00   -.9958746E-06
                             5   -.1349433E+01   -.2960500E-05

ITERATION NUMBER  4          I      VAR(I)          F(I)          TH=  4.5000
                             1   -.4012623E+00    .3658439E-07
                             2    .1213782E+01   -.1054126E-06
                             3    .5411579E+00   -.1652031E-06
                             4    .1022144E+00   -.3776356E-06
                             5   -.1019340E+01   -.1072266E-05

ITERATION NUMBER  4          I      VAR(I)          F(I)          TH=  9.0000
                             1   -.4831782E+00    .2240619E-07
                             2    .1338533E+01   -.1211789E-06
                             3    .5336417E+00   -.1375964E-06
                             4    .4500041E-02   -.3127000E-06
                             5   -.7634070E+00   -.8013006E-06
```

```
K PAR=1.147458C

ITERATION NUMBER  1          I      VAR(I)            F(I)            TH=  9.0000
                             1   -.6831780E+00    -.3585511E-08
                             2    .1338533E+01     .1657825E-08
                             3    .5336420E+00     .2025056E-07
                             4    .4500289E-02     .5777683E-07
                             5   -.7634071E+00     .2063648E-06

   WAG=    34.5888    WOP(I)=     4.4374          4.4374          4.4374
```

	P P-PJ	RHO RHO-PJ	U U-PJ	V V-PJ	R	Z
	.7319351E+06	.5560579E-01	.4975186E+04	.1057512E+04	.1043705E+01	.4158234E+00
	.7657143E+05	.5784368E-01	.4906007E+04	.9548788E+03	.9877225E+00	.4454912E+00
J= 1	.565498E+08	.955450E-02	.456618E+04	.635359E+03		
	.7935226E+06	.5947665E-01	.4849799E+04	.8676386E+03	.9353116E+00	.4717842E+00
J= 1	.566607E+08	.995251E-02	.453647E+04	.587835E+03		
J= 2	.571277E+08	.121332E-01	.421494E+04	.369864E+03		
	.8151617E+06	.6115302E-01	.4804422E+04	.7942389E+03	.8871491E+00	.4946324E+00
J= 1	.567442E+08	.101404E-01	.450736E+04	.544569E+03		
J= 2	.572302E+08	.125450E-01	.416668E+04	.341543E+03		
	.8291583E+06	.6201395E-01	.4778495E+04	.7569197E+03	.8567339E+00	.5085194E+00
J= 1	.568284E+08	.101939E-01	.448873E+04	.517888E+03		
J= 2	.572883E+08	.126599E-01	.417068E+04	.323937E+03		
J= 3	.578736E+08	.178491E-01	.369886E+04	.802348E+02		
	.8570083E+06	.6383365E-01	.4723081E+04	.6542954E+03	.7827786E+00	.5401507E+00
J= 1	.569764E+08	.101851E-01	.444442E+04	.456010E+03		
J= 2	.574110E+08	.126262E-01	.413685E+04	.287873E+03		
J= 3	.579426E+08	.180101E-01	.368138E+04	.790082E+02		
	.8739245E+06	.6493237E-01	.4689606E+04	.5926445E+03	.7305934E+00	.5607535E+00
J= 1	.570714E+08	.101168E-01	.441509E+04	.415263E+03		
J= 2	.574941E+08	.124454E-01	.411667E+04	.264963E+03		
J= 3	.580195E+08	.176372E-01	.367031E+04	.772136E+02		
	.8888178E+06	.6589906E-01	.4660094E+04	.5356132E+03	.6784081E+00	.5799354E+00
J= 1	.571573E+08	.100185E-01	.438806E+04	.376974E+03		
J= 2	.575478E+08	.122146E-01	.409904E+04	.243413E+03		
J= 3	.580712E+08	.170842E-01	.366032E+04	.746199E+02		
	.9019588E+06	.6679015E-01	.4634048E+04	.4825743E+03	.6262229E+00	.5976964E+00
J= 1	.572337E+08	.992619E-02	.436367E+04	.341003E+03		
J= 2	.576034E+08	.119835E-01	.408361E+04	.222806E+03		
J= 3	.581176E+08	.164896E-01	.365138E+04	.712681E+02		
	.9135409E+06	.6749930E-01	.4611061E+04	.4329558E+03	.5740376E+00	.6140366E+00
J= 1	.573008E+08	.985490E-02	.434207E+04	.307113E+03		
J= 2	.576519E+08	.117851E-01	.407008E+04	.202862E+03		
J= 3	.581588E+08	.159453E-01	.364346E+04	.672312E+02		
	.9237368E+05	.6815764E-01	.4590805E+04	.3862415E+03	.5218524E+00	.6289558E+00
J= 1	.573584E+08	.981181E-02	.432329E+04	.275025E+03		
J= 2	.576942E+08	.116389E-01	.405821E+04	.183394E+03		
J= 3	.581949E+08	.155104E-01	.363651E+04	.625969E+02		
	.9326788E+06	.6873432E-01	.4573016E+04	.3419692E+03	.4696672E+00	.6424542E+00
J= 1	.574075E+08	.980012E-02	.430724E+04	.244446E+03		
J= 2	.577309E+08	.115531E-01	.404783E+04	.164280E+03		
J= 3	.582264E+08	.152117E-01	.363045E+04	.574562E+02		
	.9404758E+06	.6923653E-01	.4557485E+04	.2997288E+03	.4174819E+00	.6545317E+00
J= 1	.574487E+08	.981858E-02	.429375E+04	.215089E+03		
J= 2	.577627E+08	.115267E-01	.403879E+04	.145440E+03		
J= 3	.582535E+08	.150535E-01	.362524E+04	.518967E+02		
	.9472108E+06	.6966948E-01	.4544051E+04	.2591594E+03	.3652967E+00	.6651884E+00
J= 1	.574828E+08	.986251E-02	.428261E+04	.186696E+03		

J= 3	.582765E+08	.150223E-01	.362081E+04	.459982E+02		
.9529522E+06	.7003905E-01	.4532591E+04	.2199453E+03		.3131114E+00	.6744241E+00
J= 1	.575104E+08	.997493E-02	.427359E+04	.159035E+03		
J= 2	.578137E+08	.116177E-01	.402431E+04	.108376E+03		
J= 3	.582957E+08	.150930E-01	.361710E+04	.390318E+02		
.9577434E+06	.7034704E-01	.4523013E+04	.1818124E+03		.2609262E+00	.6822390E+00
J= 1	.575322E+08	.999756E-02	.426643E+04	.131914E+03		
J= 2	.578424E+08	.117086E-01	.401875E+04	.930837E+02		
J= 3	.583114E+08	.152337E-01	.361405E+04	.334580E+02		
.9614288E+06	.7059637E-01	.4515249E+04	.1445227E+03		.2087410E+00	.6886329E+00
J= 1	.575492E+08	.100717E-01	.426098E+04	.105176E+03		
J= 2	.578479E+08	.118094E-01	.401421E+04	.719152E+02		
J= 3	.583238E+08	.154095E-01	.361163E+04	.269283E+02		
.9646234E+06	.7078878E-01	.4509251E+04	.1078692E+03		.1565557E+00	.6936060E+00
J= 1	.575418E+08	.101393E-01	.425694E+04	.786975E+02		
J= 2	.578590E+08	.119056E-01	.401071E+04	.538469E+02		
J= 3	.583333E+08	.155870E-01	.360979E+04	.202852E+02		
.9667534E+06	.7092547E-01	.4504988E+04	.7167033E+02		.1043705E+00	.6971582E+00
J= 1	.575764E+08	.101930E-01	.425419E+04	.523055E+02		
J= 2	.576482E+08	.119842E-01	.400823E+04	.359549E+02		
J= 3	.583399E+08	.157360E-01	.360849E+04	.135639E+02		
.9680273E+06	.7100719E-01	.4502438E+04	.3576373E+02		.5218524E-01	.6992896E+00
J= 1	.575754E+08	.102276E-01	.425259E+04	.261706E+02		
J= 2	.578733E+08	.120356E-01	.400674E+04	.179144E+02		
J= 3	.583439E+08	.158362E-01	.360773E+04	.679364E+01		
.9684513E+06	.7103436E-01	.4501589E+04	0.		0.	.7000000E+00
J= 1	.575770E+08	.102395E-01	.425207E+04	0.		
J= 2	.578750E+08	.120534E-01	.400624E+04	0.		
J= 3	.583452E+08	.158710E-01	.360747E+04	0.		

**** NOZZLE WEIGHT FLOW, WDOT= 47.901 LB/SEC

**** NOZZLE DISCHARGE COEFFICIENT, CD= 1.01105

GAS-PARTICLE FLOW

CHARACTERISTIC CALCULATION

IWALL = 4 OPTION SPECIFIED

CONTOURED NOZZLE OPTION SELECTED. WALL TABLE IS

I	X-ZS(I)	RWRS(I)	WALL SLOPE
1	.7816[illegible]E+00	.11590E+01	.42447E+00
2	.12815E+0[illegible]	.13712E+01	.42404E+00
3	.15000E+01	.14640E+01	.42399E+00
4	.25000E+01	.[illegible]885E+01	.42906E+00
5	.35000E+01	.23129E+0[illegible]	[illegible]
6	.45000E+01	.27374E+01	.49129E+00
7	.55210E+01	.32095E+01	.46263E+00
8	.66550E+01	.36833E+01	.33194E+00
9	.88875E+01	.43951E+01	.32891E+00
10	.10624E+ 2	.49626E+01	.[illegible]804E+00
11	.12735E+02	.55532E+01	.24933E+00

WALL COORDINATES

R/R*	X/R*	SLOPE(DEG)
1.0437048	.4158234	
1.0445067	.4195794	12.05500
1.0453159	.4233319	12.16500
1.0461322	.4270839	12.27500
1.0469557	.4308363	12.38500
1.0477865	.4345836	12.49500
1.0486244	.4383302	12.60500
1.0494696	.4420758	12.71500
1.0503219	.4458197	12.82500
1.0511814	.4495620	12.93500
1.0520481	.4533026	13.04500
1.0529216	.4570416	13.15500
1.0538030	.4607789	13.26500
1.0546912	.4645144	13.37500
1.0555866	.4682443	13.48500
1.0564891	.4719805	13.59500
1.0573989	.4757100	13.70500
1.0583157	.4794345	13.81500
1.0592398	.4831664	13.92500
1.0601718	.4868415	14.03500
1.0611093	.4906148	14.14500
1.0620548	.4943363	14.25500
1.0630074	.4980544	14.36500
1.0639672	.5017734	14.47500
1.0649341	.5054898	14.58500
1.0659081	.5092039	14.69500
1.0668893	.5129162	14.80500
1.0678776	.5166265	14.91500
1.0688730	.5203350	15.02500
1.0698755	.5240415	15.13500
1.0708852	.5277461	15.24500
1.0719019	.5314488	15.35500
1.0729258	.5351495	15.46500

1.0739567	.5388482	15.57500
1.0749948	.5425449	15.68500
1.0760408	.5462397	15.79500
1.0770972	.5499324	15.90500
1.0781516	.5536231	16.01500
1.0792180	.5573110	16.12500
1.0802915	.5609984	16.23500
1.0813721	.5646829	16.34500
1.0824597	.5683654	16.45500
1.0835544	.5720458	16.56500
1.0846562	.5757240	16.67500
1.0857650	.5794001	16.78500
1.0868809	.5830741	16.89500
1.0880039	.5867460	17.00500
1.0891339	.5904157	17.11500
1.0902709	.5940832	17.22500
1.0914150	.5977485	17.33500
1.0925661	.6014116	17.44500
1.0937242	.6050725	17.55500
1.0948894	.6087312	17.66500
1.0960616	.6123876	17.77500
1.0972408	.6160418	17.88500
1.0984270	.6196937	17.99500
1.0996203	.6233433	18.10500
1.1008205	.6269906	18.21500
1.1020277	.6306356	18.32500
1.1032420	.6342783	18.43500
1.1044637	.6379186	18.54500
1.1056914	.6415566	18.65500
1.1069266	.6451923	18.76500
1.1081688	.6488255	18.87500
1.1094179	.6524564	18.98500
1.1106740	.6560848	19.09500
1.1119371	.6597108	19.20500
1.1132071	.6633344	19.31500
1.1144841	.6669556	19.42500
1.1157680	.6705743	19.53500
1.1170589	.6741905	19.64500
1.1183567	.6778043	19.75500
1.1196615	.6814155	19.86500
1.1209732	.6850243	19.97500
1.1222918	.6886305	20.08500
1.1236173	.6922341	20.19500
1.1249498	.6958353	20.30500
1.1262891	.6994338	20.41500
1.1276354	.7030298	20.52500
1.1289886	.7066232	20.63500
1.1303487	.7102139	20.74500
1.1317156	.7138021	20.85500
1.1330895	.7173876	20.96500
1.1344702	.7209705	21.07500
1.1358578	.7245508	21.18500
1.1372523	.7281283	21.29500
1.1386536	.7317032	21.40500
1.1400618	.7352754	21.51500
1.1414768	.7388448	21.62500
1.1428988	.7424116	21.73500
1.1443275	.7459754	21.84500
1.1457631	.7495368	21.95500
1.1472055	.7530953	22.06500
1.1486548	.7566511	22.17500
1.1501108	.7602040	22.28500
1.1515737	.7637541	22.39500
1.1530434	.7673014	22.50500
1.1545200	.7708459	22.61500
1.1560033	.7743876	22.72500

1.1576936	.7779264	22.03500
1.1589963	.7814623	22.94500
1.1640899	.7934762	22.99981
1.1693964	.8059732	22.99945
1.1749038	.8189531	22.99911
1.1806181	.8324166	22.99878
1.1865373	.8463618	22.99848
1.1926415	.8607906	22.99821
1.1989005	.8757026	22.99796
1.2055265	.8910972	22.99775
1.2122634	.9069750	22.99758
1.2192073	.9233357	22.99746
1.2263561	.9401796	22.99738
1.2337099	.9575060	22.99735
1.2412687	.9753157	22.99738
1.2490325	.9936083	22.99747
1.2570013	1.0123839	22.99763
1.2651752	1.0316426	22.99786
1.2735543	1.0513840	22.99817
1.2821385	1.0716085	22.99856
1.2909279	1.0923160	22.99904
1.2999225	1.1135056	22.99962
1.3091225	1.1351790	23.00029
1.3185278	1.1573362	23.00107
1.3281385	1.1799756	23.00196
1.3379548	1.2030980	23.00296
1.3479767	1.2267033	23.00409
1.3582042	1.2507916	23.00536
1.3686375	1.2753629	23.00675
1.3792766	1.3004171	23.00820
1.3901212	1.3259543	23.00880
1.4011704	1.3519745	23.00833
1.4124206	1.3784776	23.00648
1.4238868	1.4054638	23.00325
1.4355309	1.4329329	22.99857
1.4474005	1.4608850	22.99236
1.4594614	1.4893208	22.98455
1.4717216	1.5182380	22.97517
1.4841887	1.5476598	22.96500
1.4968397	1.5775770	22.95600
1.5096976	1.6078400	22.94912
1.5227958	1.6387399	22.94232
1.5360169	1.6700724	22.93657
1.5494783	1.7018886	22.93191
1.5631377	1.7341875	22.92839
1.5770079	1.7669693	22.92600
1.5910714	1.8002361	22.92503
1.6053468	1.8339818	22.92529
1.6198276	1.8682126	22.92693
1.6345085	1.9029263	22.93000
1.6494011	1.9381229	22.93456
1.6645077	1.9738024	22.94069
1.6798166	2.0099652	22.94841
1.6953377	2.0466108	22.95782
1.7110761	2.0837394	22.96896
1.7270292	2.1213500	22.98196
1.7431898	2.1594459	22.99671
1.7595787	2.1980230	23.01348
1.7761868	2.2370836	23.03218
1.7930131	2.2766260	23.05297
1.8100880	2.3166533	23.07580
1.8273459	2.3571627	23.10080
1.8448802	2.3981558	23.12835
1.8625968	2.4396303	23.15804
1.8805846	2.4815888	23.19012
1.8987811	2.5240299	23.22439

1.9172283	2.5669592	23.25416
1.9359055	2.6103616	23.28123
1.9548870	2.6542516	23.29930
1.9739266	2.6986248	23.31012
1.9932570	2.7434809	23.31344
2.0127915	2.7888200	23.30901
2.0325224	2.8346421	23.29650
2.0524414	2.8809472	23.27592
2.0725600	2.9277352	23.24672
2.0928889	2.9750062	23.20873
2.1132385	3.0227602	23.16167
2.1338185	3.0709972	23.10525
2.1545387	3.1197171	23.03910
2.1753863	3.1689200	22.96319
2.1963589	3.2186059	22.87693
2.2174196	3.2687747	22.78010
2.2385789	3.3194264	22.67237
2.2598155	3.3705614	22.55342
2.2811149	3.4221791	22.42209
2.3024622	3.4742799	22.28043
2.3238629	3.5268636	22.12681
2.3452689	3.5799303	21.96645
2.3667793	3.6334800	21.88494
2.3884171	3.6875126	21.82396
2.4102272	3.7420282	21.80695
2.4322575	3.7970268	21.82907
2.4545880	3.8525083	21.89764
2.4771818	3.9084729	22.01109
2.5001862	3.9649206	22.17096
2.5236236	4.0218509	22.37791
2.5478418	4.0792643	22.63270
2.5728682	4.1371607	22.93595
2.5971881	4.1955401	23.28820
2.6230144	4.2544025	23.68982
2.6495110	4.3137478	24.14105
2.6770545	4.3735732	24.64197
2.7054271	4.4338875	25.19246
2.7348860	4.4946817	25.79225
2.7652554	4.5559590	26.42326
2.7967160	4.6177192	26.99420
2.8289869	4.6799623	27.47622
2.8622535	4.7426885	27.86920
2.8961076	4.8058976	28.17299
2.9305271	4.8695897	28.38700
2.9653867	4.9337648	28.51022
3.0005579	4.9984229	28.54128
3.0359802	5.0635639	28.47800
3.0712880	5.1291879	28.31817
3.1064875	5.1952949	28.08467
3.1416419	5.2618849	27.80580
3.1759585	5.3289577	27.22556
3.2090631	5.3965134	26.64278
3.2420675	5.4645525	25.94192
3.2750651	5.5330763	25.11682
3.3080910	5.6020791	24.20946
3.3360687	5.6715664	23.33580
3.3650766	5.7415376	22.51415
3.3931884	5.8119916	21.75475
3.4206985	5.8829201	21.05560
3.4470085	5.9543670	20.42205
3.4730502	6.0262504	19.85792
3.4985625	6.0986300	19.36439
3.5235220	6.1715064	18.95052
3.5482771	6.2448562	18.61319
3.5727771	6.3186987	18.35706
3.5971362	6.3930083	18.18450

3.6215865	6.4678087	18.09775
3.6461892	6.5430922	18.09875
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3.7751652	6.9267541	18.96698
3.8022886	7.0049354	19.13318
3.8298086	7.0835997	19.28195
3.8577010	7.1627469	19.41303
3.8859405	7.2423772	19.52617
3.9145008	7.3224904	19.62111
3.9433565	7.4030865	19.69757
3.9724733	7.4841657	19.75526
4.0018276	7.5657278	19.79388
4.0313869	7.6477729	19.81311
4.0611194	7.7303069	19.81261
4.0909921	7.8133120	19.79204
4.1209712	7.8968060	19.75102
4.1510214	7.9807830	19.68917
4.1811066	8.0652429	19.60608
4.2111585	8.1501858	19.50133
4.2412289	8.2356117	19.37447
4.2711876	8.3215206	19.22504
4.3010234	8.4079125	19.05256
4.3306935	8.4947873	18.85446
4.3601547	8.5821451	18.63627
4.3893604	8.6699859	18.39141
4.4182729	8.7583096	18.12454
4.4468648	8.8471163	17.85917
[illegible]	8.9364060	17.60619
4.5032943	9.0261787	17.36600
4.5311278	9.1164343	17.13896
4.5587603	9.2071729	16.92543
[illegible]	9.2983945	16.72574
4.6135869	9.3900990	16.54024
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[illegible]	9.7617470	15.94678
4.7477050	9.8558666	15.83718
4.7743744	9.9504688	15.74371
[illegible]	10.0455542	15.66667
4.8277367	10.1411225	15.60637
[illegible]	10.2371738	15.56310
4.8813267	10.3337081	15.53713
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[illegible]	10.6262088	15.56586
[illegible]	10.7246756	[illegible]
[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	15.68116
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	15.67621
[illegible]	11.3256149	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	15.58400
[illegible]	11.6326066	15.52996
[illegible]	11.7359003	15.46397
[illegible]	[illegible]	15.38585
[illegible]	11.9439411	15.29539
[illegible]	12.0486859	15.19261
[illegible]	12.1539137	15.07671
[illegible]	12.2596245	14.94806
[illegible]	12.3658183	14.80626

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     5.4709655       12.4724950         14.65100
     5.4986436       12.5795547         14.48230
     5.5260808       12.6872974         14.29970
     5.5532461       12.7954230         14.10302
     0.0000000        0.0000000

LRC ID     R          Z         MACH      TG       VG    THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK              VPK              THETA-K          TPK      DPK/DG          DPK/DP0            RPK

  0 15  1.04370    .41582   1.2913  5193.8  5086.3  12.000  .85838   .29606  .34491 0.00000  1.2575  201.73  0

LRC ID     R          Z         MACH      TG       VG    THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK              VPK              THETA-K          TPK      DPK/DG          DPK/DP0            RPK

  1 14   .98772    .44549   1.2653  5223.2  4998.1  11.014  .86325   .30973  .35879 0.00000  0.0000    0.00  0

  1  5  1.05945    .48402   1.3767  5103.5  5375.6  14.035  .84346   .26369  .31263 0.00000  1.2668  203.22  0

LRC ID     R          Z         MACH      TG       VG    THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK              VPK              THETA-K          TPK      DPK/DG          DPK/DP0            RPK

  2 14   .93531    .47178   1.2463  5246.7  4926.8  10.143  .86713   .32098  .37016  .16677  0.0000    0.00  0
      1   .227190E+01   .457440E+04   .738324E+01   .530895E+04   .166774E+00   .160400E+00   .251725E-05

  2  4   .99658    .50372   1.3339  5150.7  5232.2  12.874  .85127   .28073  .32970  .16829  0.0000    0.00  5
      1   .267479E+01   .477682E+04   .937378E+01   .524216E+04   .168295E+00   .144204E+00   .251725E-05

  2  5  1.07694    .54938   1.4496  5024.6  5616.0  15.905  .83042   .23791  .28650 0.00000  1.2761  204.72  5

LRC ID     R          Z         MACH      TG       VG    THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK              VPK              THETA-K          TPK      DPK/DG          DPK/DP0            RPK

  3  1   .88715    .49468   1.2279  5265.2  4869.6   9.387  .87019   .33013  .37938  .37090  0.0000    0.00  0
      1   .214585E+01   .454814E+04   .688896E+01   .532112E+04   .165792E+00   .163427E+00   .251725E-05
      2   .786254E+01   .420851E+04   .465017E+01   .537597E+04   .205108E+00   .202181E+00   .466971E-05

  3  4   .94011    .52152   1.2913  5196.2  5087.5  11.549  .85879   .29843  .34751  .37635  0.0000    0.00  5
      1   .242588E+01   .469655E+04   .842622E+01   .527028E+04   .169319E+00   .152881E+00   .251725E-05
      2   .827047E+01   .434271E+04   .600945E+01   .532801E+04   .207034E+00   .186935E+00   .466971E-05

  3  4  1.00413    .55757   1.3819  5098.1  5392.7  14.228  .84257   .26089  .30963  .16836  0.0000    0.00  5
      1   .255720E+01   .493599E+04   .107365E+02   .517028E+04   .168365E+00   .135451E+00   .251725E-05

  3  5  1.09520    .60989   1.5103  4967.7  5840.8  17.775  .81771   .21488  .26279 0.00000  1.2851  206.16  5

LRC ID     R          Z         MACH      TG       VG    THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK              VPK              THETA-K          TPK      DPK/DG          DPK/DP0            RPK

  4 14   .88473    .50862   1.2185  5275.7  4837.1   8.931  .87192   .33539  .38456  .36843  0.0000    0.00  0
      1   .208208E+01   .451851E+04   .65[illegible]41E+01   .532868E+04   .164382E+00   .164291E+00   .251725E-05
      2   .771570E+01   .418324E+04   .444174E+01   .538201E+04   .204146E+00   .204034E+00   .466971E-05

  4  4   .94362    .55314   1.3194  5145.5  5183.0  12.365  .85371   .28529  .33417  .37969  0.0000    0.00  5
      1   .244252E+01   .477515E+04   .913235E+01   .526393E+04   .170501E+00   .148041E+00   .251725E-05
      2   .827348E+01   .441449E+04   .655727E+01   .530435E+04   .209190E+00   .181633E+00   .466971E-05

  4  4  1.01287    .59178   1.4124  5044.8  5493.7  15.035  .83707   .24807  .29731  .16070  0.0000    0.00  5
      1   .249688E+01   .503211E+04   .115518E+02   .519892E+04   .168703E+00   .130322E+00   .251725E-05

  4  5  1.10800    .64834   1.5615  4900.5  5974.4  18.875  .80991   .20172  .24936 0.00000  1.2918  207.10  5

LRC ID     R          Z         MACH      TG       VG    THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK              VPK              THETA-K          TPK      DPK/DG          DPK/DP0            RPK

  5  1   .78278    .54015   1.1984  5297.6  4788.2   7.887  .87554   .34667  .39595  .63950  0.0000    0.00  0
      1   .196575E+01   .444775E+04   .585821E+01   .534610E+04   .159557E+00   .164168E+00   .251725E-05
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         2   .737120E+01   .414685E+04   .398066E+01   .539726E+04   .197798E+00   .203490E+00   .466971E-05
         3   .235704E+02   .368222E+04   .122947E+01   .546218E+04   .282141E+00   .290260E+00   .867473E-05

 5  4   .85890    .57774  1.2626  5226.7  4989.0  10.432  .86382  .30970  .35852  .66891  0.0000    0.00  5
         1   .210491E+01   .465753E+04   .775283E+01   .528543E+04   .166071E+00   .154701E+00   .251725E-05
         2   .751418E+01   .432317E+04   .562672E+01   .533835E+04   .207068E+00   .192891E+00   .466971E-05
         3   .239313E+02   .381862E+04   .234556E+01   .541340E+04   .295769E+00   .275520E+00   .867473E-05

 5  4   .95347    .62870  1.3737  5104.2  5363.9  14.069  .84358  .25980  .30797  .38252  0.0000    0.00  5
         1   .220018E+01   .495949E+04   .107487E+02   .518410E+04   .171242E+00   .137029E+00   .251725E-05
         2   .765760E+01   .458515E+04   .819944E+01   .524835E+04   .211281E+00   .169068E+00   .466971E-05

 5  4  1.03094    .67333  1.4795  4988.9  5711.7  16.928  .82453  .22307  .27054  .16885  0.0000    0.00  5
         1   .231257E+01   .525519E+04   .134360E+02   .508693E+04   .168855E+00   .118694E+00   .251725E-05

 5  5  1.14219    .74063  1.6692  4779.0  6306.7  21.735  .78983  .17086  .21633 0.00000  1.3053  209.40  5

LRC ID     R         Z        MACH      TG       VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
         K       REK          VPK           THETA-K          TPK         DPK/DG          DPK/DP0            RPK

 6  1   .73059    .56075  1.1846  5310.6  4726.9   7.203  .87769  .35350  .40276  .61900  0.0000    0.00  0
         1   .190775E+01   .443457E+04   .537317E+01   .535728E+04   .155709E+00   .162947E+00   .251725E-05
         2   .714678E+01   .412519E+04   .368267E+01   .540586E+04   .191667E+00   .200576E+00   .466971E-05
         3   .229752E+02   .367112E+04   .120517E+01   .546888E+04   .271624E+00   .284250E+00   .867473E-05

 6  4   .86121    .62619  1.2925  5192.5  5090.4  11.349  .85817  .29313  .34158  .67694  0.0000    0.00  5
         1   .208262E+01   .475196E+04   .856219E+01   .525517E+04   .166998E+00   .148211E+00   .251725E-05
         2   .734698E+01   .441634E+04   .641537E+01   .530854E+04   .208987E+00   .185477E+00   .466971E-05
         3   .234095E+02   .389987E+04   .310977E+01   .538681E+04   .300957E+00   .267101E+00   .867473E-05

 6  4   .96180    .68169  1.4107  5061.7  5485.5  15.073  .83656  .24344  .29100  .38682  0.0000    0.00  5
         1   .219622E+01   .508821E+04   .118085E+02   .516434E+04   .171932E+00   .129997E+00   .251725E-05
         2   .740678E+01   .469909E+04   .922921E+01   .521061E+04   .212886E+00   .160962E+00   .466971E-05

 6  4  1.04535    .73087  1.5297  4931.7  5871.3  18.222  .81507  .20548  .25210  .14986  0.0000    0.00  5
         1   .224373E+01   .540211E+04   .146701E+02   .503766E+04   .169862E+00   .111265E+00   .251725E-05

 6  5  1.16976    .80686  1.7273  4712.5  6480.7  22.999  .77885  .15578  .20001 0.00000  1.3157  211.07  5

LRC ID     R         Z        MACH      TG       VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
         K       REK          VPK           THETA-K          TPK         DPK/DG          DPK/DP0            RPK

 7  1   .[illegible]    .[illegible]994  1.1765  5321.9  4690.8   6.5[illegible]7  .87955  .35952  .40876  .59660  0.0000    0.00  0
         1   .186[illegible]E+01   .44[illegible]22E+04   .491[illegible]E+01   .536760E+04   .151998E+00   .161431E+00   .251725E-05
         2   .69[illegible]E+01   .41862[illegible]E+04   .339[illegible]E+01   .541336E+04   .185364E+00   .196057E+00   .466971E-05
         3   .22[illegible]E+02   .366108E+04   .11[illegible]E+01   .54749[illegible]E+04   .259248E+00   .275338E+00   .867473E-05

 7  4   .86615    .67667  1.3228  5158.2  51[illegible]2.4  12.223  .85250  .27706  .32439  .68498  0.0000    0.00  5
         1   .2[illegible]E+01   .4[illegible]E+04   .[illegible]E+0[illegible]   .52[illegible]E+04   .167783E+00   .141659E+00   .251725E-05
         2   .7[illegible]E+01   .45[illegible]E+04   .[illegible]E+01   .527[illegible]E+04   .210831E+00   .178020E+00   .466971E-05
         3   .23[illegible]E+02   .39[illegible]E+04   .[illegible]E+01   .53606[illegible]E+04   .306391E+00   .258722E+00   .867473E-05

 7  4   .97671    .73686  1.4475  5019.3  5606.9  16.069  .82955  .22767  .27460  .38716  0.0000    0.00  5
         1   .2[illegible]E+01   .5197[illegible]E+04   .126165E+02   .510524E+04   .172425E+00   .123205E+00   .251725E-05
         2   .[illegible]E+01   .48[illegible]E+04   .10[illegible]E+02   .51736[illegible]E+04   .214530E+00   .153114E+00   .466971E-05

 7  4  1.0[illegible]    .[illegible]87  1.5765  4875.6  60[illegible]4.0  19.436  .80577  .18928  .23491  .17066  0.0000    0.00  5
         1   .2[illegible]E+01   .556652E+04   .159[illegible]E+02   .498[illegible]E+04   .170681E+00   .104165E+00   .251725E-05

 7  5  1.19[illegible]    .[illegible]   1.7511  4685.[illegible]  4951.1  22.998  .77431  .16989  .19357 0.00000  1.3259  212.70  5

LRC ID     R         Z        MACH      TG       VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
         K       REK          VPK           THETA-K          TPK         DPK/DG          DPK/DP0            RPK

 8  1   .[illegible]    .[illegible]770  1.1476  5331.7  4659.1   5.945  .88117  .36686  .41[illegible]  .57526  0.0000    0.00  0
         [illegible]   .[illegible]E+01   .437497E+04   .4448[illegible]E+01   .537639E+04   .148705E+00   .159974E+00   .251725E-05
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      2   .675705E+01    .408968E+04    .317302E+01    .541990E+04    .179527E+00    .193131E+00    .466971E-05
      3   .219690E+02    .365208E+04    .111016E+01    .548042E+04    .247025E+00    .265744E+00    .867473E-05

  8  4   .86771   .72265  1.3510  5125.1  5286.1  12.992  .84703   .26236  .30974  .69180  0.0000     0.00  5
      1   .198098E+01    .493737E+04    .101535E+02    .519394E+04    .168277E+00    .135427E+00    .251725E-05
      2   .696245E+01    .459669E+04    .795952E+01    .524964E+04    .212373E+00    .170915E+00    .466971E-05
      3   .222415E+02    .405728E+04    .458596E+01    .533445E+04    .311154E+00    .250413E+00    .867473E-05

  8  4   .98074   .78802  1.4832  4977.0  5718.9  16.943  .82256   .21340  .25944  .38937  0.0000     0.00  5
      1   .201232E+01    .530867E+04    .137504E+02    .506709E+04    .173345E+00    .116850E+00    .251725E-05
      2   .702401E+01    .491705E+04    .111572E+02    .513744E+04    .216024E+00    .145620E+00    .466971E-05

  8  4  1.07839   .84704  1.6292  4817.1  6180.2  20.696  .79613   .17337  .21777  .17215  0.0000     0.00  5
      1   .209006E+01    .568783E+04    .170502E+02    .493863E+04    .172152E+00    .[illegible]4085E-01    .251725E-05

  8  5  1.22586   .93901  1.7746  4657.8  6620.4  22.997  .76900   .14422  .18735 0.00000  1.3359   214.30  5

LOC ID    R         Z        MACH     TG      VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK           VPK           THETA-K          TPK          DPK/DG         DPK/DPG          RPK

  9  1   .57404   .61404  1.1596  5340.2  4631.3   5.364  .88258   .36952  .41868  .55682  0.0000     0.00  0
      1   .179520E+01    .435292E+04    .404577E+01    .538426E+04    .146008E+00    .158826E+00    .251725E-05
      2   .659258E+01    .407513E+04    .285338E+01    .542561E+04    .174596E+00    .189934E+00    .466971E-05
      3   .215488E+02    .364408E+04    .185713E+01    .548527E+04    .236229E+00    .256982E+00    .867473E-05

  9  4   .87187   .77080  1.3782  5092.9  5375.6  13.691  .84171   .24863  .29539  .69799  0.0000     0.00  5
      1   .190858E+01    .502515E+04    .108780E+02    .516414E+04    .160662E+00    .129449E+00    .251725E-05
      2   .670320E+01    .460234E+04    .867320E+01    .522122E+04    .213731E+00    .164039E+00    .466971E-05
      3   .215652E+02    .413336E+04    .528944E+01    .530878E+04    .315596E+00    .242221E+00    .867473E-05

  9  4   .99170   .86139  1.5107  4933.6  5834.1  17.838  .81539   .19938  .24452  .39219  0.0000     0.00  5
      1   .194073E+01    .541743E+04    .144457E+02    .502891E+04    .174376E+00    .110753E+00    .251725E-05
      2   .676104E+01    .502151E+04    .120580E+02    .510166E+04    .217862E+00    .138412E+00    .466971E-05

  9  4  1.09700   .90565  1.678[illegible]  4758.0  6329.5  21.863  .78649   .15894  .20209  .17325  0.0000     0.00  5
      1   .200325E+01    .582710E+04    .181915E+02    .488891E+04    .173255E+00    .909730E-01    .251725E-05

  9  5  1.25395  1.00497  1.7999  4628.9  6692.9  22.998  .76503   .13042  .18094 0.00000  1.3457   215.08  5

LOC ID    R         Z        MACH     TG      VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK           VPK           THETA-K          TPK          DPK/DG         DPK/DPG          RPK

 10  1   .52185   .62896  1.1527  5347.7  4607.0   4.809  .88381   .37365  .42277  .54229  0.0000     0.00  0
      1   .176674E+01    .433283E+04    .363995E+01    .539106E+04    .143958E+00    .158132E+00    .251725E-05
      2   .644737E+01    .406236E+04    .258748E+01    .543058E+04    .170745E+00    .187579E+00    .466971E-05
      3   .211771E+02    .363784E+04    .[illegible]162E+01    .548953E+04    .227566E+00    .249973E+00    .867473E-05

 10  4   .87441   .81803  1.4043  5061.3  5460.6  14.323  .83648   .23586  .28196  .70356  0.0000     0.00  5
      1   .183240E+01    .510952E+04    .115648E+02    .513503E+04    .168957E+00    .123782E+00    .251725E-05
      2   .665815E+01    .474495E+04    .934205E+01    .519352E+04    .214958E+00    .157483E+00    .466971E-05
      3   .204639E+02    .420782E+04    .594619E+01    .528352E+04    .319641E+00    .234176E+00    .867473E-05

 10  4  1.00355   .89490  1.555[illegible]  4891.0  5945.0  18.678  .80835   .18620  .23045  .39[illegible]  0.0000     0.00  5
      1   .186268E+01    .552749E+04    .155049E+02    .499094E+04    .175196E+00    .104904E+00    .251725E-05
      2   .668846E+01    .517342E+04    .129229E+02    .506025E+04    .219612E+00    .131500E+00    .466971E-05

 10  4  1.11700   .94467  1.7183  4711.7  6466.4  22.437  .77870   .14779  .18900  .17252  0.0000     0.00  5
      1   .181859E+01    .5994[illegible]E+04    .192608E+02    .484087E+04    .172517E+00    .850749E-01    .251725E-05

 10  5  1.29188  1.07899  1.8250  4599.8  6765.2  22.999  .76022   .13279  .17407 0.00000  1.3553   217.42  5

LOC ID    R         Z        MACH     TG      VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
      K        REK           VPK           THETA-K          TPK          DPK/DG         DPK/DPG          RPK

 11  1   .64947   .64245  1.1467  5354.1  4585.8   4.277  .88488   .37724  .42670  .53198  0.0000     0.00  0
      1   .173946E+01    .431417E+04    .324018E+01    .539604E+04    .142588E+00    .157944E+00    .251725E-05
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        1   .475544E-01    .935386E+04    .173872E+02    .350925E+04    .157643E+00    .513190E-02   .251725E-05
        2   .265245E+00    .905419E+04    .187878E+02    .416700E+04    .155387E+00    .505846E-02   .466971E-05

 44  4  4.67311 10.15109  3.2936  3016.0  9886.2  15.227  .49846   .00690  .01384  .11963  0.0000     0.00  5
        1   .933216E-01    .978608E+04    .169873E+02    .324945E+04    .119628E+00    .430051E-02   .251725E-05

 44  5  4.95174 10.58690  3.4273  2913.3 10110.8  15.566  .48148   .00650  .01349 0.00000  1.8326   293.99  5

LOC ID   R        Z         MACH     TG       VG     THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF       ISP   IT
      K      REK             VPK            THETA-K           TPK      DPK/DG          DPK/DP0            RPK

 45  3  0.00000  3.51884  2.1971  4039.3  7632.0   0.000  .66757   .03372  .05051  .77935  0.0000     0.00  5
        1   .238684E+00    .736079E+04  0.                   .421152E+04    .169148E+00    .222032E-01   .251725E-05
        2   .119081E+01    .690238E+04  0.                   .434749E+04    .231805E+00    .304243E-01   .466971E-05
        3   .418047E+01    .625316E+04  0.                   .452649E+04    .378377E+00    .496619E-01   .867473E-05

 45  4  2.88890  7.86683  2.8441  3341.8  8986.2  18.455  .55230   .00668  .01209  .73491  0.0000     0.00  5
        1   .664239E-01    .877696E+04    .177760E+02    .402099E+04    .156636E+00    .491956E-02   .251725E-05
        2   .260756E+00    .865355E+04    .168200E+02    .416700E+04    .210123E+00    .659967E-02   .466971E-05
        3   .106734E+01    .771732E+04    .166655E+02    .416700E+04    .308152E+00    .115628E-01   .867473E-05

 45  4  4.16005  9.51687  3.1177  3152.1  9566.9  16.848  .52096   .00625  .01200  .31308  0.0000     0.00  4
        1   .439814E-01    .940488E+04    .172958E+02    .347572E+04    .157702E+00    .491664E-02   .251725E-05
        2   .249870E+00    .910124E+04    .185963E+02    .416700E+04    .155379E+00    .484420E-02   .466971E-05

 45  4  4.75839 10.63423  3.3147  2998.1  9918.4  14.922  .48549   .00669  .01350  .11950  0.0000     0.00  5
        1   .855619E-01    .981211E+04    .165383E+02    .322754E+04    .119498E+00    .419158E-02   .251725E-05

 45  5  5.02768 10.85848  3.4571  2887.5 10153.9  15.087  .47723   .00613  .01284 0.00000  1.8374   294.76  5

 45  4  2.95233  8.07824  2.8713  3312.6  9032.2  18.795  .54748   .00616  .01126  .74458  0.0000     0.00  5
        1   .538930E-01    .882134E+04    .175220E+02    .398291E+04    .157331E+00    .460245E-02   .251725E-05
        2   .268946E+00    .869880E+04    .169718E+02    .416700E+04    .212311E+00    .621081E-02   .466971E-05
        3   .106963E+01    .775816E+04    .167366E+02    .416700E+04    .374837E+00    .109681E-01   .867473E-05

 45  4  4.22857  9.78138  3.1387  3131.9  9600.5  16.555  .51761   .00602  .01103  .31030  0.0000     0.00  5
        1   .438717E-01    .944967E+04    .171745E+02    .346574E+04    .158441E+00    .477702E-02   .251725E-05
        2   .264044E+00    .914500E+04    .184128E+02    .416700E+04    .153857E+00    .464096E-02   .466971E-05

 45  4  4.89840 10.70690  3.3413  2974.4  9959.7  16.806  .48159   .00630  .01300  .12004  0.0000     0.00  5
        1   .734075E-01    .983935E+04    .161655E+02    .320775E+04    .120836E+00    .408172E-02   .251725E-05

 45  5  5.16256 11.12526  3.4845  2864.0 10192.0  15.076  .47334   .00580  .01226 0.00000  1.8419   295.48  5

LOC ID   R        Z         MACH     TG       VG     THETA-G  TG/TG0   PG/PG0  DG/DG0  SDK/DG    CF       ISP   IT
      K      REK             VPK            THETA-K           TPK      DPK/DG          DPK/DP0            RPK

 46  3  0.00000  3.60277  2.2382  3987.9  7723.1   0.000  .65875   .03005  .04562  .79010  0.0000     0.00  5
        1   .216552E+00    .765840E+04  0.                   .416744E+04    .170364E+00    .201954E-01   .251725E-05
        2   .108699E+01    .690230E+04  0.                   .430400E+04    .230544E+00    .278035E-01   .466971E-05
        3   .382691E+01    .633804E+04  0.                   .448273E+04    .395192E+00    .456500E-01   .867473E-05

 46  4  3.01727  8.29366  2.8944  3285.8  9073.1  19.012  .54306   .00571  .01052  .74225  0.0000     0.00  5
        1   .603316E-01    .886362E+04    .177604E+02    .392931E+04    .197532E+00    .430700E-02   .251725E-05
        2   .235734E+00    .854275E+04    .171290E+02    .416700E+04    .213004E+00    .566170E-02   .466971E-05
        3   .953150E+00    .779847E+04    .168167E+02    .416700E+04    .380063E+00    .104814E-01   .867473E-05

 46  4  4.32273 10.05601  3.1587  3128.5  9619.4  15.005  .51572   .00594  .01140  .30191  0.0000     0.00  5
        1   .449921E-01    .946110E+04    .146592E+02    .341570E+04    .152494E+00    .459000E-02   .251725E-05
        2   .247964E+00    .918930E+04    .181472E+02    .416700E+04    .160271E+00    .445679E-02   .466971E-05

 46  4  4.97916 10.95170  3.3715  2968.0 10005.9  14.804  .48732   .00605  .01262  .12201  0.0000     0.00  5
        1   .562019E-01    .987081E+04    .158629E+02    .314906E+04    .122607E+00    .395790E-02   .251725E-05

 46  5  5.18155 11.40716  3.5085  2863.0 10225.9  15.076  .46000   .00556  .01170 0.00000  1.8485   296.22  5
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46  4  3.08352  8.51233   2.9206  3259.2  9113.1  19.243  .53865   .00530  .00983  .759    0.0000     0.00  5
       1   .568253E-01    .890435E+04   .179874E+02   .388916E+04    .157987E+00   .403591E-02   .251725E-05
       2   .223080E+00    .858543E+04   .172868E+02   .416700E+04    .215292E+00   .549982E-02   .466971E-05
       3   .900110E+00    .783864E+04   .168978E+02   .416700E+04    .386124E+00   .986308E-02   .867473E-05

46  4  4.41841 10.35939   3.1535  3118.1  9624.4  15.109  .51534   .00598  .01160  .28892  0.0000     0.00  5
       1   .643670E-01    .952621E+04   .165991E+02   .338715E+04    .146884E+00   .442717E-02   .251725E-05
       2   .271036E+00    .923122E+04   .179257E+02   .416700E+04    .142032E+00   .428094E-02   .466971E-05

46  4  5.00067 11.27710   3.4025  2920.9 10050.7  14.962  .48275   .00571  .01182  .12450  0.0000     0.00  5
       1   .483880E-01    .990472E+04   .156518E+02   .316658E+04    .124499E+00   .302429E-02   .251725E-05

46  5  5.26105 11.69300   3.5277  2827.3 10252.1  15.464  .46727   .00533  .01141 0.00000  1.8510   296.94  5

LRC ID    R        Z       MACH     TO      VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
       K      REK           VPK            THETA-K          TPK      DPK/DG          DPK/DPG          RPK

47  3  0.00000  3.84686   2.2753  3937.6  7803.4   0.000  .65077   .02699  .04147  .79706  0.0000     0.00  5
       1   .190548E+00    .754410E+04  0.                         .416700E+04    .171036E+00   .184306E-01   .251725E-05
       2   .987963E+00    .707864E+04  0.                         .427058E+04    .236374E+00   .254713E-01   .466971E-05
       3   .350802E+01    .641807E+04  0.                         .446019E+04    .390454E+00   .420747E-01   .867473E-05

47  4  3.14866  8.72618   2.9430  3234.8  9148.6  19.437  .53463   .00494  .00924  .76402  0.0000     0.00  5
       1   .532275E-01    .894190E+04   .181937E+02   .385333E+04    .158086E+00   .379422E-02   .251725E-05
       2   .210716E+00    .862539E+04   .174373E+02   .416700E+04    .216218E+00   .510945E-02   .466971E-05
       3   .851523E+00    .787661E+04   .169813E+02   .416700E+04    .390517E+00   .937280E-02   .867473E-05

47  4  4.50637 10.63374   3.1647  3108.4  9643.6  14.445  .51373   .00595  .01158  .28153  0.0000     0.00  5
       1   .730152E-01    .950480E+04   .161781E+02   .336192E+04    .144067E+00   .433364E-02   .251725E-05
       2   .288002E+00    .926712E+04   .176247E+02   .416700E+04    .137468E+00   .413513E-02   .466971E-05

47  4  5.07383 11.53979   3.4295  2897.4 10089.5  14.991  .47086   .00542  .01131  .12577  0.0000     0.00  5
       1   .438637E-01    .993787E+04   .155174E+02   .314859E+04    .125767E+00   .369660E-02   .251725E-05

47  5  5.33602 11.95875   3.5426  2814.8 10272.5  15.192  .46520   .00510  .01113 0.00000  1.8551   297.59  5

47  4  3.21512  8.94326   2.9438  3212.1  9180.8  19.586  .53088   .00462  .00870  .76902  0.0000     0.00  5
       1   .402769E-01    .897752E+04   .183817E+02   .382821E+04    .158889E+00   .357275E-02   .251725E-05
       2   .107894E+00    .866388E+04   .178829E+02   .416700E+04    .216889E+00   .489981E-02   .466971E-05
       3   .844652E+00    .791602E+04   .170668E+02   .416700E+04    .394122E+00   .890702E-02   .867473E-05

47  4  4.59086 10.93117   3.1822  3093.0  9673.0  13.943  .51110   .00586  .01147  .27643  0.0000     0.00  5
       1   .738545E-01    .958540E+04   .157068E+02   .333566E+04    .142446E+00   .424428E-02   .251725E-05
       2   .284108E+00    .930614E+04   .172763E+02   .416046E+04    .133984E+00   .399224E-02   .466971E-05

47  4  5.15160 11.82013   3.4537  2876.4 10123.9  14.964  .47539   .00517  .01087  .12604  0.0000     0.00  4
       1   .406959E-01    .997142E+04   .154863E+02   .312990E+04    .126041E+00   .355975E-02   .251725E-05

47  5  5.41884 12.24102   3.5579  2801.9 10293.6  14.968  .46308   .00502  .01035 0.00000  1.8593   298.26  4

LRC ID    R        Z       MACH     TO      VG    THETA-G  TG/TG0  PG/PG0  DG/DG0  SDK/DG    CF      ISP   IT
       K      REK           VPK            THETA-K          TPK      DPK/DG          DPK/DPG          RPK

48  3  0.00000  4.01801   2.3177  3889.6  7883.4   0.000  .64286   .02420  .03745  .80695  0.0000     0.00  4
       1   .170815E+00    .742946E+04  0.                         .416700E+04    .172084E+00   .168306E-01   .251725E-05
       2   .807872E+00    .716373E+04  0.                         .423416E+04    .230556E+00   .233340E-01   .466971E-05
       3   .321583E+01    .649583E+04  0.                         .442985E+04    .396324E+00   .307650E-01   .867473E-05

48  4  3.28292  9.14155   2.9830  3158.2  9211.4  19.719  .52725   .00433  .00821  .77246  0.0000     0.00  5
       1   .457021E-01    .901193E+04   .185567E+02   .318960E+04    .157982E+00   .337082E-02   .251725E-05
       2   .184021E+00    .870091E+04   .177232E+02   .416700E+04    .217878E+00   .463147E-02   .466971E-05
       3   .761211E+00    .795850E+04   .171523E+02   .416700E+04    .306979E+00   .846975E-02   .867473E-05

48  4  4.49172 11.27982   3.2064  3073.5  9700.5  13.502  .50707   .00573  .01127  .27372  0.0000     0.00  5
       1   .487955E-01    .961721E+04   .152505E+02   .331023E+04    .141960E+00   .415771E-02   .251725E-05
       2   .290908E+00    .934036E+04   .169198E+02   .409258E+04    .131783E+00   .384018E-02   .466971E-05
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48	6	5.22852	12.10066	3.4736	2859.2	10151.8	14.834	.47255	.00497	.01052	.12537	0.0000	0.00	S
	1	.390750E-01	.100044E+05	.153043E+02	.311205E+04	.125373E+00	.342835E-02	.251725E-05						
48	5	5.48351	12.52107	3.5639	2796.9	10301.5	14.482	.46225	.00496	.01074	0.00000	1.0633	298.90	S
48	6	3.35005	9.38335	3.0015	3170.9	9237.6	19.767	.52405	.00408	.00779	.77194	0.0000	0.00	S
	1	.411139E-01	.904343E+04	.187056E+02	.376045E+04	.157417E+00	.318585E-02	.251725E-05						
	2	.172850E+00	.873672E+04	.178544E+02	.416700E+04	.216493E+00	.438145E-02	.466971E-05						
	3	.719118E+00	.798613E+04	.172372E+02	.416700E+04	.398029E+00	.805544E-02	.867473E-05						
48	6	4.78254	11.53158	3.2342	3047.0	9757.5	13.491	.50358	.00550	.01092	.27490	0.0000	0.00	S
	1	.592681E-01	.965733E+04	.148810E+02	.328521E+04	.143283E+00	.406427E-02	.251725E-05						
	2	.273229E+00	.937692E+04	.165803E+02	.404669E+04	.131620E+00	.373343E-02	.466971E-05						
48	6	5.38448	12.38673	3.4504	2844.6	10175.1	14.607	.47017	.00482	.01025	.12399	0.0000	0.00	S
	1	.390536E-01	.100358E+05	.151873E+02	.309452E+04	.123[illegible]E+00	.330365E-02	.251725E-05						
48	5	5.51973	12.66240	3.5687	2792.9	10308.0	14.300	.46159	.00492	.01065	0.00000	1.0652	299.22	S
48	5	5.53752	12.73283	3.5671	2794.3	10305.8	14.103	.46182	.00493	.01068	0.00000	1.0662	299.38	S
48	5	5.54637	12.76805	3.5708	2791.8	10309.8	14.103	.46140	.00490	.01063	0.00000	1.0667	299.45	S
48	5	5.55080	12.78568	3.5715	2790.6	10311.8	14.103	.46120	.00489	.01060	0.00000	1.0669	299.49	S
48	5	5.55301	12.79449	3.5723	2789.9	10312.8	14.103	.46110	.00488	.01059	0.00000	1.0670	299.51	S
48	5	5.55315	12.79505	3.5723	2789.9	10312.9	14.103	.46109	.00488	.01059	0.00000	1.0671	299.51	S
48	5	5.55322	12.79530	3.5724	2789.9	10312.9	14.103	.46109	.00488	.01059	0.00000	1.0671	299.51	S
48	5	5.55325	12.79543	3.5724	2789.9	10312.9	14.103	.46109	.00488	.01059	0.00000	1.0671	299.51	S

IP= 03

SUMMARY OUTPUT FROM TD2P MODULE

A/A*	ISP(TD2P)	ETA(TD2P)
2.00000	224.30076	.94139
4.00000	247.33876	.93939
6.00000	259.56891	.94104
10.00000	270.64651	.93402
20.00000	288.60879	.94397
30.00000	298.84883	.95224
30.83850	299.51306	.95276

** TIME AVERAGED VALUES**

ETA(TD2P)= .9514[illegible] ISP(TD2P)= 297.713 LBF-SEC/LBM

** ETA(TD2P) CORRECTED FOR THROAT EROSION= .94778

TURBULENT BOUNDARY LAYER LOSS MODULE (TBL)

EXTENDED DELTA VALIDATION CASE

NZETA	= VELOCITY PROFILE POWER LAW EXPONENT	= 7
IPRINT	= PRINT AT EVERY CALCULATED POINT(=1) OR AT INPUT INTERVALS(=0)	= 0
IXTAB	= NUMBER OF POINTS IN X .VS. Y .VS. M TABLES	= 80
ICTAB	= NUMBER OF POINTS IN CP .VS. T TABLE	= 0
ITWTAB	= WALL TEMP. OPTION -- ADIABATIC(=-1), CONSTANT(=0), TABLE(=1)	= -1
IEDGE	= EDGE CONDITION OPTION--CALCULATED(=0), INPUT(.GE.1)	= 0
T0	= FREE STREAM STAGNATION TEMPERATURE	= 5.9675500E+03
P0	= FREE STREAM STAGNATION PRESSURE	= 5.6859840E+06
GAMO	= STAGNATION RATIO OF SPECIFIC HEATS	= 1.1706900E+00
PRANDTL	= STAGNATION PRANDTL NUMBER	= 4.5463900E-01
ZMU0	= STAGNATION VISCOSITY	= 6.1135400E-05
ZNVIS	= EXPONENT OF VISCOSITY-TEMPERATURE LAW	= 6.7175300E-01
ZNSTAN	= BOUNDARY LAYER INTERACTION EXPONENT	= 1.0000000E-01
DXMAX	= MAXIMUM STEP SIZE	= 2.9974441E-02
THETAI	= INITIAL VALUE OF MOMENTUM THICKNESS	= 1.0000000E-04
PHII	= INITIAL VALUE OF ENERGY THICKNESS	= 1.0000000E-04
EPSZ	= GEOMETRY... AXISYMMETRIC(=1.), PLANE(=0.)	= 1.0000000E+00
RBAR	= GAS CONSTANT	= 7.8770747E+01
FJ	= CONVERSION BETWEEN THERMAL AND WORK UNITS	= 7.7820000E+02
G	= PROPORTIONALITY CONSTANT IN EQUATION -- F=M/G*A	= 3.2174000E+01
SCALE	= CONTOUR SCALE FACTOR	= 1.7046816E-01

I	X	Y	MACH NUMBER
1	-7.1387763E-01	5.8637498E-01	5.5222200E-02
2	-6.6133339E-01	5.5093456E-01	6.2464500E-02
3	-6.0470615E-01	5.1549814E-01	7.1257400E-02
4	-5.5625669E-01	4.8004150E-01	8.2083700E-02
5	-5.0371765E-01	4.4462388E-01	9.5633600E-02
6	-4.5117821E-01	4.0918465E-01	1.1292500E-01
7	-3.9863807E-01	3.7374623E-01	1.3551700E-01
8	-3.4609073E-01	3.3630059E-01	1.6592400E-01
9	-2.9354649E-01	3.0287117E-01	2.0847600E-01
10	-2.4102303E-01	2.6743275E-01	2.7142900E-01
11	-1.8848379E-01	2.3229459E-01	3.7237400E-01
12	-1.3594455E-01	2.0537045E-01	5.0070000E-01
13	-8.3405088E-02	1.8430994E-01	6.7009000E-01
14	-3.0866403E-02	1.7908408E-01	8.5466100E-01
15	2.1672281E-02	1.7912571E-01	1.0450400E+00
16	8.6382156E-02	1.8987809E-01	1.3747500E+00
17	9.8047015E-02	1.9219950E-01	1.4495800E+00
18	1.0880809E-01	1.9569833E-01	1.5192700E+00
19	[illegible]	1.9774272E-01	1.5614000E+00
20	[illegible]	2.0384655E-01	1.6691700E+00
21	[illegible]	2.0876491E-01	1.7272600E+00
22	[illegible]	2.1378144E-01	1.7511500E+00
23	[illegible]	2.1877498E-01	1.7768000E+00
24	[illegible]	[illegible]	1.7900700E+00
25	[illegible]	2.2877678E-01	1.8250600E+00
26	[illegible]	2.3378258E-01	1.8582700E+00
27	2.1674681E-01	2.3880284E-01	1.8756300E+00
28	2.2664566E-01	2.4384818E-01	1.9005200E+00
29	[illegible]	2.4881311E-01	1.9254900E+00
30	[illegible]	[illegible]	1.9501700E+00
31	[illegible]	2.5914447E-01	1.9765300E+00
32	[illegible]	[illegible]	1.9988700E+00
33	[illegible]	2.6955295E-01	2.0220300E+00
34	[illegible]	[illegible]	2.0475200E+00
35	[illegible]	[illegible]	2.0723500E+00
36	[illegible]	[illegible]	2.0973900E+00
37	[illegible]	2.9134027E-01	2.1220700E+00

38	3.5741750E-01	2.9712628E-01	2.1490900E+00
39	3.6647901E-01	3.0308177E-01	2.1757700E+00
40	3.8106023E-01	3.0925676E-01	2.2031500E+00
41	3.9418882E-01	3.1569056E-01	2.2314500E+00
42	4.1200624E-01	3.2242414E-01	2.2607000E+00
43	4.2861627E-01	3.2951290E-01	2.2919900E+00
44	4.7215179E-01	3.4820787E-01	2.3679300E+00
45	5.1915138E-01	3.6844037E-01	2.4421100E+00
46	5.7026644E-01	3.9022590E-01	2.5091200E+00
47	6.2471351E-01	4.1281291E-01	2.5646100E+00
48	6.8045676E-01	4.3520808E-01	2.6330200E+00
49	7.4057887E-01	4.5990919E-01	2.7536000E+00
50	7.8120510E-01	4.7800050E-01	2.8642400E+00
51	8.2489589E-01	4.9953059E-01	2.9927700E+00
52	8.7064583E-01	5.2387943E-01	3.0809900E+00
53	9.1864144E-01	5.4984969E-01	3.1196200E+00
54	9.6459972E-01	5.7356275E-01	3.0952100E+00
55	1.0093835E+00	5.9413478E-01	3.0523100E+00
56	1.0510258E+00	6.1084260E-01	2.9950100E+00
57	1.0923967E+00	6.2573970E-01	2.9858700E+00
58	1.1319825E+00	6.3903023E-01	2.9969700E+00
59	1.1722827E+00	6.5221724E-01	3.0343300E+00
60	1.2136514E+00	6.6595929E-01	3.0907700E+00
61	1.2541910E+00	6.8069897E-01	3.1634000E+00
62	1.2977386E+00	6.9537762E-01	3.1861300E+00
63	1.3417647E+00	7.1008096E-01	3.2234300E+00
64	1.3855788E+00	7.2602750E-01	3.2563400E+00
65	1.4308702E+00	7.4315926E-01	3.2831300E+00
66	1.4780080E+00	7.5943377E-01	3.3029100E+00
67	1.5238128E+00	7.7544772E-01	3.3151500E+00
68	1.5494329E+00	7.9056754E-01	3.3104300E+00
69	1.6129542E+00	8.0630265E-01	3.3191800E+00
70	1.6542654E+00	8.1812124E-01	3.3339100E+00
71	1.7035871E+00	8.3145281E-01	3.3432400E+00
72	1.7494787E+00	8.4462554E-01	3.3566400E+00
73	1.7958629E+00	8.5770085E-01	3.3749600E+00
74	1.8412738E+00	8.7033765E-01	3.3996000E+00
75	1.8896245E+00	8.8372792E-01	3.4273300E+00
76	1.9378085E+00	8.9728079E-01	3.4570600E+00
77	1.9855118E+00	9.1044469E-01	3.4864900E+00
78	2.0358061E+00	9.2474169E-01	3.5084500E+00
79	2.0868282E+00	9.3692000E-01	3.5277100E+00
80	2.1302458E+00	9.5195273E-01	3.5425800E+00
81	2.1864287E+00	9.6557088E-01	3.5579200E+00
82	2.2346177E+00	9.7663193E-01	3.5638000E+00
83	2.2598152E+00	9.8509809E-01	3.5407200E+00
84	2.2723096E+00	9.8827100E-01	3.5470500E+00
85	2.2786003E+00	9.8985044E-01	3.5700400E+00
86	2.2818603E+00	9.9064105E-01	3.5715400E+00
87	2.2836108E+00	9.9103547E-01	3.5722800E+00
88	2.2839801E+00	9.9108865E-01	3.5723300E+00
89	2.2835538E+00	9.9107205E-01	3.5723500E+00
90	2.2835715E+00	9.9107830E-01	3.5723600E+00

CONTOUR PROPERTIES		FLOW PROPERTIES		BOUNDARY LAYER		HEAT TRANSFER		INTERNAL INTEGRALS		COEFFICIENTS	
X =	-.71397E+00	M =	.55222E-01	DELTA =	.10287E-02	HS =	0.	ZETA =	.10000E+01	CF =	.13129E-01
XL =	0.	TE =	.50650E+04	DELTA =	.10287E-02	QW =	0.	I1 =	.13007E-01	CM =	0.
Y =	.88417E+00	TW =	.50672E+04	DELT* =	.12867E-03	SUMQ =	0.	I2 =	.12690E+00	RETH =	.68863E+02
DY/DX =	-.67481E+00	TAW =	.50672E+04	THETA =	.10080E-03	FORCE =	0.	I3 =	0.	REL =	0.
		DM/DX =	.12309E+00	PHI =	.10080E-03	LAT.F =	0.	I2P =	.13007E-01	REDM =	.68863E+02
		UE =	.23312E+01	H =	.12867E+01			I3P =	0.	RED* =	.59276E+02
		PE =	.56798E+05								

CONTOUR PROPERTIES FLOW PROPERTIES BOUNDARY LAYER HEAT TRANSFER INTERNAL INTEGRALS COEFFICIENTS

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X =     -.66133E+00 M =      .67464E-01 DELTA = .33733E-02 HG =    0.            ZETA =   .82965E+00 CF =     .81920E-02
XL =     .63374E-01 TE =     .59655E+04 DELTB = .91269E-03 QW =    0.            I4   =   .73651E-02 CH =    0.
Y =      .85096E+00 TW =     .59671E+04 DELT* = .62189E-03 SUMQ =  0.            I5   =   .65221E-02 RETH =   .17079E+03
DY/DX = -.67451E+00 TAW =    .59671E+04 THETA = .32792E-03 FORCE =  .21449E+00   I6   =   .20053E-01 REXL =   .33007E+05
                    DM/DX =  .15260E+00 PHI =   .73402E-04 LAT.F = 0.            I7   =   .96937E-01 REPH =   .38334E+02
                    UE =     .26369E+03 H =     .12866E+01                       I1P  =   .13806E-01 RED* =   .21974E+03
                    PE =     .56729E+05

CONTOUR PROPERTIES    FLOW PROPERTIES    BOUNDARY LAYER    HEAT TRANSFER    INTERNAL INTEGRALS    COEFFICIENTS

X =     -.60879E+00 M =      .71257E-01 DELTA = .43948E-02 HG =    0.            ZETA =   .77046E+00 CF =     .71054E-02
XL =     .12475E+00 TE =     .59648E+04 DELTB = .70027E-03 QW =    0.            I4   =   .40829E-02 CH =    0.
Y =      .81550E+00 TW =     .59669E+04 DELT* = .54972E-03 SUMQ =  0.            I5   =   .90038E-02 RETH =   .28300E+03
DY/DX = -.67451E+00 TAW =    .59669E+04 THETA = .42721E-03 FORCE =  .41290E+00   I6   =   .15517E-01 REXL =   .75264E+05
                    DM/DX =  .19671E+00 PHI =   .53030E-04 LAT.F = 0.            I7   =   .10947E+00 REPH =   .31499E+02
                    UE =     .30079E+03 H =     .12868E+01                       I1P  =   .13808E-01 RED* =   .32643E+03
                    PE =     .56690E+05

CONTOUR PROPERTIES    FLOW PROPERTIES    BOUNDARY LAYER    HEAT TRANSFER    INTERNAL INTEGRALS    COEFFICIENTS

X =     -.55426E+00 M =      .82084E-01 DELTA = .47923E-02 HG =    0.            ZETA =   .72939E+00 CF =     .65474E-02
XL =     .19012E+00 TE =     .59640E+04 DELTB = .52633E-03 QW =    0.            I4   =   .35157E-02 CH =    0.
Y =      .48006E+00 TW =     .59667E 04 DELT* = .59955E-03 SUMQ =  0.            I5   =   .10370E-01 RETH =   .31038E+03
DY/DX = -.67451E+00 TAW =    .59667E+04 THETA = .46582E-03 FORCE =  .63105E+00   I6   =   .10010E-01 REXL =   .12904E+06
                    DM/DX =  .23198E+00 PHI =   .37309E-04 LAT.F = 0.            I7   =   .11497E+00 REPH =   .25800E+02
                    UE =     .34846E+03 H =     .12871E+01                       I1P  =   .13803E-01 RED* =   .40978E+03
                    PE =     .56635E+05

CONTOUR PROPERTIES    FLOW PROPERTIES    BOUNDARY LAYER    HEAT TRANSFER    INTERNAL INTEGRALS    COEFFICIENTS

X =     -.50372E+00 M =      .95636E-01 DELTA = .48171E-02 HG =    0.            ZETA =   .69514E+00 CF =     .61080E-02
XL =     .25349E+00 TE =     .59427E+04 DELTB = .37782E-03 QW =    0.            I4   =   .25994E-02 CH =    0.
Y =      .44442E+00 TW =     .59664E+04 DELT* = .60284E-03 SUMQ =  0.            I5   =   .11206E-01 RETH =   .37239E+03
DY/DX = -.67451E+00 TAW =    .59664E+04 THETA = .46820E-03 FORCE =  .88504E+00   I6   =   .48110E-02 REXL =   .20162E+06
                    DM/DX =  .29351E+00 PHI =   .25520E-04 LAT.F = 0.            I7   =   .11817E+00 REPH =   .20290E+02
                    UE =     .40361E+03 H =     .12876E+01                       I1P  =   .13081E-01 RED* =   .47940E+03
                    PE =     .55554E+05

CONTOUR PROPERTIES    FLOW PROPERTIES    BOUNDARY LAYER    HEAT TRANSFER    INTERNAL INTEGRALS    COEFFICIENTS

X =     -.45118E+00 M =      .11292E+00 DELTA = .46104E-02 HG =    0.            ZETA =   .66383E+00 CF =     .50260E-02
XL =     .31687E+00 TE =     .59608E+04 DELTB = .26191E-03 QW =    0.            I4   =   .19280E-02 CH =    0.
Y =      .40918E+00 TW =     .59660E+04 DELT* = .57723E-03 SUMQ =  0.            I5   =   .11955E-01 RETH =   .42000E+03
DY/DX = -.67451E+00 TAW =    .59660E+04 THETA = .44806E-03 FORCE =  .11917E+01   I6   =   .47103E-02 REXL =   .29760E+06
                    DM/DX =  .37958E+00 PHI =   .16858E-04 LAT.F = 0.            I7   =   .12026E+00 REPH =   .15035E+02
                    UE =     .47651E+03 H =     .12883E+01                       I1P  =   .13078E-01 RED* =   .54110E+03
                    PE =     .56434E+05

CONTOUR PROPERTIES    FLOW PROPERTIES    BOUNDARY LAYER    HEAT TRANSFER    INTERNAL INTEGRALS    COEFFICIENTS

X =     -.39866E+00 M =      .13552E+00 DELTA = .42606E-02 HG =    0.            ZETA =   .63360E+00 CF =     .57096E-02
XL =     .38024E+00 TE =     .59578E+04 DELTB = .17406E-03 QW =    0.            I4   =   .14137E-02 CH =    0.
Y =      .37375E+00 TW =     .59653E+04 DELT* = .53384E-03 SUMQ =  0.            I5   =   .12467E-01 RETH =   .44452E+03
DY/DX = -.67451E+00 TAW =    .59653E+04 THETA = .41199E-03 FORCE =  .15735E+01   I6   =   .32677E-02 REXL =   .42665E+06
                    DM/DX =  .54434E+00 PHI =   .10746E-04 LAT.F = 0.            I7   =   .12172E+00 REPH =   .12057E+02
                    UE =     .57170E+03 H =     .12894E+01                       I1P  =   .13073E-01 RED* =   .59090E+03
                    PE =     .56248E+05

CONTOUR PROPERTIES    FLOW PROPERTIES    BOUNDARY LAYER    HEAT TRANSFER    INTERNAL INTEGRALS    COEFFICIENTS

X =     -.34610E+00 M =      .15802E+00 DELTA = .38751E-02 HG =    0.            ZETA =   .60320E+00 CF =     .55200E-02
XL =     .44361E+00 TE =     .59529E+04 DELTB = .11124E-03 QW =    0.            I4   =   .10126E-02 CH =    0.
Y =      .33831E+00 TW =     .59642E+04 DELT* = .47978E-03 SUMQ =  0.            I5   =   .12905E-01 RETH =   .50821E+03
DY/DX = -.67451E+00 TAW =    .59642E+04 THETA = .37157E-03 FORCE =  .20642E+01   I6   =   .21903E-02 REXL =   .60079E+06
                    DM/DX =  .60433E+00 PHI =   .65120E-05 LAT.F = 0.            I7   =   .12279E+00 REPH =   .90000E+01
                    UE =     .64969E+03 H =     .12912E+01                       I1P  =   .13066E-01 RED* =   .64822E+03
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                 PE =     .55946E+05

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER      HEAT TRANSFER      INTERNAL INTEGRALS     COEFFICIENTS

X =      -.29356E+00 M =       .20848E+00 DELTA =  .33408E-02 HG =    0.         ZETA =   .57202E+00 CF =      .53602E-02
XL =      .50609E+00 TE =      .59445E+04 DELTB =  .66966E-04 QW =    0.         I4   =   .70236E-03 CM =   0.
Y =       .30287E+00 TW =      .59622E+04 DELT* =  .41985E-03 SUMQ =  0.         I5   =   .13160E-01 RETM =    .55312E+03
DY/DX = -.87452E+00 TAW =     .59622E+04 THETA =  .32435E-03 FORCE =  .27170E+01 I6   =   .14289E-02 REXL =    .86459E+06
                 DM/DX =   .10041E+01 PHI =    .37123E-05 LAT.F = 0.         I7   =   .12347E+00 REPM =    .63300E+01
                 UE =      .67051E+03 H =      .12944E+01                     I1P  =   .13849E-01 RED* =    .71590E+03
                 PE =      .55425E+05

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER      HEAT TRANSFER      INTERNAL INTEGRALS     COEFFICIENTS

X =      -.26102E+00 M =       .27143E+00 DELTA =  .28256E-02 HG =    0.         ZETA =   .53908E+00 CF =      .52067E-02
XL =      .57036E+00 TE =      .59285E+04 DELTB =  .37383E-04 QW =    0.         I4   =   .46204E-03 CM =   0.
Y =       .28763E+00 TW =      .59585E+04 DELT* =  .35665E-03 SUMQ =  0.         I5   =   .13395E-01 RETM =    .59975E+03
DY/DX = -.67171E+00 TAW =     .59585E+04 THETA =  .27609E-03 FORCE =  .36277E+01 I6   =   .80715E-03 REXL =    .12481E+07
                 DM/DX =   .15598E+01 PHI =    .19494E-05 LAT.F = 0.         I7   =   .12395E+00 REPM =    .42657E+01
                 UE =      .11623E+04 M =      .13005E+01                     I1P  =   .13819E-01 RED* =    .77990E+03
                 PE =      .54652E+05

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER      HEAT TRANSFER      INTERNAL INTEGRALS     COEFFICIENTS

X =      -.19868E+00 M =       .37237E+00 DELTA =  .23121E-02 HG =    0.         ZETA =   .50260E+00 CF =      .5052[illegible]E-02
XL =      .63360E+00 TE =      .58945E+04 DELTB =  .18732E-04 QW =    0.         I4   =   .27891E-03 CM =   0.
Y =       .23229E+00 TW =      .59507E+04 DELT* =  .29402E-03 SUMQ =  0.         I5   =   .13551E-01 RETM =    .65131E+03
DY/DX = -.59863E+00 TAW =     .59507E+04 THETA =  .22384E-03 FORCE =  .69019E+01 I6   =   .50416E-03 REXL =    .18636E+07
                 DM/DX =   .22540E+01 PHI =    .90644E-06 LAT.F = 0.         I7   =   .12419E+00 REPM =    .26375E+01
                 UE =      .15426E+04 M =      .13135E+01                     I1P  =   .13784E-01 RED* =    .85552E+03
                 PE =      .52626E+05

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER      HEAT TRANSFER      INTERNAL INTEGRALS     COEFFICIENTS

X =      -.13596E+00 M =       .50828E+00 DELTA =  .20757E-02 HG =    0.         ZETA =   .46678E+00 CF =      .48301E-02
XL =      .69268E+00 TE =      .58329E+04 DELTB =  .97579E-05 QW =    0.         I4   =   .16061E-03 CM =   0.
Y =       .20537E+00 TW =      .59365E+04 DELT* =  .2626[illegible]E-03 SUMQ =  0.  I5   =   .13619E-01 RETM =    .73657E+03
DY/DX = -.61817E+00 TAW =     .59365E+04 THETA =  .19436E-03 FORCE =  .70372E+01 I6   =   .27631E-03 REXL =    .25987E+07
                 DM/DX =   .28333E+01 PHI =    .4342[illegible]E-06 LAT.F = 0.  I7   =   .12615E+00 REPM =    .16291E+01
                 UE =      .21217E+04 M =      .13375E+01                     I1P  =   .13633E-01 RED* =    .98533E+03
                 PE =      .49016E+05

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER      HEAT TRANSFER      INTERNAL INTEGRALS     COEFFICIENTS

X =      -.89608E-01 M =       .67009E+00 DELTA =  .19457E-02 HG =    0.         ZETA =   .43309E+00 CF =      .45781E-02
XL =      .74704E+00 TE =      .57774E+04 DELTB =  .56011E-05 QW =    0.         I4   =   .03101E-04 CM =   0.
Y =       .18835E+00 TW =      .59144E+04 DELT* =  .25036E-03 SUMQ =  0.         I5   =   .13607E-01 RETM =    .852[illegible]E+03
DY/DX = -.26330E+00 TAW =     .59144E+04 THETA =  .18451E-03 FORCE =  .90063E+01 I6   =   .15200E-03 REXL =    .33[illegible]E+07
                 DM/DX =   .33155E+01 PHI =    .23237E-06 LAT.F = 0.         I7   =   .12386E+00 REPM =    .10[illegible]E+01
                 UE =      .27761E+04 M =      .13750E+01                     I1P  =   .13441E-01 RED* =    .11724E+04
                 PE =      .43866E+05

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER      HEAT TRANSFER      INTERNAL INTEGRALS     COEFFICIENTS

X =      -.20867E-01 M =       .85666E+00 DELTA =  .20141E-02 HG =    0.         ZETA =   .40440E+00 CF =      .43527E-02
XL =      .80124E+00 TE =      .56003E+04 DELTB =  .36426E-05 QW =    0.         I4   =   .56305E-04 CM =   0.
Y =       .17000E+00 TW =      .58828E+04 DELT* =  .27630E-03 SUMQ =  0.         I5   =   .13527E-01 RETM =    .97157E+03
DY/DX = -.87775E-01 TAW =     .58828E+04 THETA =  .19150E-03 FORCE =  .13658E+02 I6   =   .88275E-04 REXL =    .40030E+07
                 DM/DX =   .37986E+01 PHI =    .13025E-06 LAT.F = 0.         I7   =   .12331E+00 REPM =    .7[illegible]07E+00
                 UE =      .35039E+04 M =      .14320E+01                     I1P  =   .13159E-01 RED* =    .13914E+04
                 PE =      .37600E+05

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER      HEAT TRANSFER      INTERNAL INTEGRALS     COEFFICIENTS

X =       .21672E-01 M =       .10050E+01 DELTA =  .21412E-02 HG =    0.         ZETA =   .38396E+00 CF =      .41664E-02
XL =      .85303E+00 TE =      .54184E+04 DELTB =  .26588E-05 QW =    0.         I4   =   .35749E-04 CM =   0.
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V =     .17913E+00  TW =     .59408E+04 DELT* =  .30725E-03 SUMQ =  0.             I5  =   .13308E-01 RETH =  [illegible]
DY/DX = .61786E-01  TAW =    .59408E+04 THETA =  .20307E-03 FORCE =  .18720E+02    I6  =   .54320E-04 REXL =  [illegible]
                    DM/DX =  .43475E+01 PHI =    .91313E-07 LAT.F = 0.             I7  =   .12249E+00 REPH =  .60125E+00
                    UE =     .42849E+04 H =      .15130E+01                        I1P =   .12770E-01 RED* =  .16193E+04
                    PE =     .30079E+05 DEL F = -.12070E+01 DEL I = -.25215E-01

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS     COEFFICIENTS

X =     .86382E-01  M =      .13767E+01 DELTA =  .24350E-02 HG =    0.             ZETA =  .36231E+00 CF =    .40314E-02
XL =    .91940E+00  TE =     .51033E+04 DELTB =  .19955E-05 QW =    0.             I4  =   .21920E-04 CH =    0.
Y =     .18908E+00  TW =     .57680E+04 DELT* =  .37275E-03 SUMQ =  0.             I5  =   .13110E-01 RETH =  .11010E+04
DY/DX = .29621E+00  TAW =    .57680E+04 THETA =  .22384E-03 FORCE =  .24800E+02    I6  =   .32350E-04 REXL =  [illegible]
                    DM/DX =  .64257E+01 PHI =    .61200E-07 LAT.F = 0.             I7  =   .12096E+00 REPH =  [illegible]
                    UE =     .53755E+04 H =      .16653E+01                        I1P =   .12109E-01 RED* =  [illegible]
                    PE =     .20260E+05 DEL F =  .29729E+01 DEL I =  .62064E-01

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS     COEFFICIENTS

X =     .88467E-01  M =      .14496E+01 DELTA =  .24022E-02 HG =    0.             ZETA =  .35017E+00 CF =    .40204E-02
XL =    .93147E+00  TE =     .50263E+04 DELTB =  .19210E-05 QW =    0.             I4  =   .20230E-04 CH =    0.
Y =     .19220E+00  TW =     .57498E+04 DELT* =  .38060E-03 SUMQ =  0.             I5  =   .13036E-01 RETH =  .10847E+04
DY/DX = .28500E+00  TAW =    .57498E+04 THETA =  .22777E-03 FORCE =  .26074E+02    I6  =   .29750E-04 REXL =  [illegible]
                    DM/DX =  .43639E+01 PHI =    .47693E-07 LAT.F = 0.             I7  =   .12055E+00 REPH =  .27474E+00
                    UE =     .56158E+04 H =      .17064E+01                        I1P =   .11940E-01 RED* =  .10509E+04
                    PE =     .18278E+05 DEL F =  .37236E+01 DEL I =  .77734E-01

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS     COEFFICIENTS

X =     .10881E+00  M =      .15193E+01 DELTA =  .25609E-02 HG =    0.             ZETA =  .35642E+00 CF =    .40193E-02
XL =    .94272E+00  TE =     .49473E+04 DELTB =  .18713E-05 QW =    0.             I4  =   .18858E-04 CH =    0.
Y =     .19566E+00  TW =     .57320E+04 DELT* =  .40671E-03 SUMQ =  0.             I5  =   .12962E-01 RETH =  .10601E+04
DY/DX = .32810E+00  TAW =    .57320E+04 THETA =  .23270E-03 FORCE =  .27262E+02    I6  =   .27590E-04 REXL =  .43271E+07
                    DM/DX =  .62585E+01 PHI =    .54974E-07 LAT.F = 0.             I7  =   .12014E+00 REPH =  .25233E+00
                    UE =     .58405E+04 H =      .17470E+01                        I1P =   .11776E-01 RED* =  .10668E+04
                    PE =     .16508E+05 DEL F =  .43700E+01 DEL I =  .91268E-01

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS     COEFFICIENTS

X =     .11571E+00  M =      .15615E+01 DELTA =  .26200E-02 HG =    0.             ZETA =  .35465E+00 CF =    .40102E-02
XL =    .94908E+00  TE =     .49001E+04 DELTB =  .18480E-05 QW =    0.             I4  =   .17993E-04 CH =    0.
Y =     .19774E+00  TW =     .57211E+04 DELT* =  .42077E-03 SUMQ =  0.             I5  =   .12916E-01 RETH =  .10624E+04
DY/DX = .34278E+00  TAW =    .57211E+04 THETA =  .23721E-03 FORCE =  .28427E+02    I6  =   .26201E-04 REXL =  .42948E+07
                    DM/DX =  .62431E+01 PHI =    .53477E-07 LAT.F = 0.             I7  =   .11980E+00 REPH =  .23904E+00
                    UE =     .59761E+04 H =      .17738E+01                        I1P =   .11672E-01 RED* =  .10044E+04
                    PE =     .15496E+05 DEL F =  .47520E+01 DEL I =  .98224E-01

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS     COEFFICIENTS

X =     .13210E+00  M =      .16102E+01 DELTA =  .27743E-02 HG =    0.             ZETA =  .35008E+00 CF =    .39965E-02
XL =    .94785E+00  TE =     [illegible] DELTB = .18152E-05 QW =    0.             I4  =   .16235E-04 CH =    0.
Y =     .20186E+00  TW =     [illegible] DELT* = .45803E-03 SUMQ =  0.             I5  =   .12795E-01 RETH =  .10390E+04
DY/DX = .39719E+00  TAW =    [illegible] THETA = .24897E-03 FORCE =  .29845E+02    I6  =   .23534E-04 REXL =  .40401E+07
                    DM/DX =  .55516E+01 PHI =    .50852E-07 LAT.F = 0.             I7  =   .11927E+00 REPH =  .21234E+00
                    UE =     [illegible] H =     .18433E+01                        I1P =   .11609E-01 RED* =  .10163E+04
                    PE =     .14123E+05 DEL F =  .56030E+01 DEL I =  .11697E+00

CONTOUR PROPERTIES    FLOW PROPERTIES     BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS     COEFFICIENTS

X =     .14488E+00  M =      .17273E+01 DELTA =  .29315E-02 HG =    0.             ZETA =  .34782E+00 CF =    .39641E-02
XL =    .98690E+00  TE =     [illegible] DELTB = .18067E-05 QW =    0.             I4  =   .14909E-04 CH =    0.
Y =     .20874E+00  TW =     .56776E+04 DELT* =  .49720E-03 SUMQ =  0.             I5  =   .12727E-01 RETH =  .10471E+04
DY/DX = .42860E+00  TAW =    [illegible] THETA = .26140E-03 FORCE =  .31151E+02    I6  =   .21690E-04 REXL =  .38250E+07
                    DM/DX =  .54842E+01 PHI =    .60405E-07 LAT.F = 0.             I7  =   .11885E+00 REPH =  .19817E+00
                    UE =     .64801E+04 H =      .18827E+01                        I1P =   .11263E-01 RED* =  .10714E+04
                    PE =     .11906E+05 DEL F =  .61903E+01 DEL I =  .12902E+00
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Y =       .94552E+00 TW =       .52363E+04 DELT* =  .11946E-01 SUMQ =  0.              I5   =    .10202E-01 RETH =    .15398E+04
DY/DX =   .26583E+00 TAW =      .52363E+04 THETA =  .31391E-02 FORCE =  .17344E+03 I6   =    .14289E-05 REXL =    .15508E+07
                     DM/DX =    .21156E+00 PHI =    .49135E-07 LAT.F = 0.              I7   =    .10403E+00 REPH =    .24102E-01
                     UE =       .10291E+05 H =      .38055E+01                         I1P  =    .60511E-02 RED* =    .50598E+04
                     PE =       .38674E+03 DEL F =  .79106E+02 DEL I =  .16514E+01

CONTOUR PROPERTIES   FLOW PROPERTIES   BOUNDARY LAYER   HEAT TRANSFER   INTERNAL INTEGRALS   COEFFICIENTS

X =       .22346E+01 M =        .35639E+01 DELTA =  .44622E-01 HG =     0.             ZETA =    .26297E+00 CF =      .27303E-02
XL =      .32131E+01 TE =       .27954E+04 DELTH =  .30082E-05 QW =     0.             I4   =    .10723E-05 CH =    0.
Y =       .07863E+00 TW =       .52351E+04 DELT* =  .12144E-01 SUMQ =  0.              I5   =    .10193E-01 RETH =    .15495E+04
DY/DX =   .25833E+00 TAW =      .52351E+04 THETA =  .31841E-02 FORCE =  .17584E+03 I6   =    .13992E-05 REXL =    .15634E+07
                     DM/DX =    .16755E+00 PHI =    .48064E-07 LAT.F = 0.              I7   =    .10398E+00 REPH =    .23770E-01
                     UE =       .10290E+05 H =      .38139E+01                         I1P  =    .60387E-02 RED* =    .59097E+04
                     PE =       .38219E+03 DEL F =  .80833E+02 DEL I =  .16875E+01

CONTOUR PROPERTIES   FLOW PROPERTIES   BOUNDARY LAYER   HEAT TRANSFER   INTERNAL INTEGRALS   COEFFICIENTS

X =       .22598E+01 M =        .35687E+01 DELTA =  .45061E-01 HG =     0.             ZETA =    .26269E+00 CF =      .27259E-02
XL =      .32302E+01 TE =       .27913E+04 DELTH =  .30898E-05 QW =     0.             I4   =    .10829E-05 CH =    0.
Y =       .08510E+00 TW =       .52342E+04 DELT* =  .12277E-01 SUMQ =  0.              I5   =    .10186E-01 RETH =    .15530E+04
DY/DX =   .25301E+00 TAW =      .52342E+04 THETA =  .32133E-02 FORCE =  .17705E+03 I6   =    .13055E-05 REXL =    .15661E+07
                     DM/DX = -.26091E-01   PHI =    .48845E-07 LAT.F = 0.              I7   =    .10393E+00 REPH =    .23617E-01
                     UE =       .10305E+05 H =      .38207E+01                         I1P  =    .60289E-02 RED* =    .59300E+04
                     PE =       .37857E+03 DEL F =  .81667E+02 DEL I =  .17049E+01

CONTOUR PROPERTIES   FLOW PROPERTIES   BOUNDARY LAYER   HEAT TRANSFER   INTERNAL INTEGRALS   COEFFICIENTS

X =       .22724E+01 M =        .35670E+01 DELTA =  .45066E-01 HG =     0.             ZETA =    .26248E+00 CF =      .27262E-02
XL =      .32521E+01 TE =       .27927E+04 DELTH =  .30682E-05 QW =     0.             I4   =    .10553E-05 CH =    0.
Y =       .08827E+00 TW =       .52345E+04 DELT* =  .12276E-01 SUMQ =  0.              I5   =    .10180E-01 RETH =    .15570E+04
DY/DX =   .25137E+00 TAW =      .52345E+04 THETA =  .32144E-02 FORCE =  .17765E+03 I6   =    .13771E-05 REXL =    .15759E+07
                     DM/DX =    .27172E+00 PHI =    .40555E-07 LAT.F = 0.              I7   =    .10395E+00 REPH =    .23529E-01
                     UE =       .10303E+05 H =      .38184E+01                         I1P  =    .60310E-02 RED* =    .59677E+04
                     PE =       .37982E+03 DEL F =  .82193E+02 DEL I =  .17159E+01

CONTOUR PROPERTIES   FLOW PROPERTIES   BOUNDARY LAYER   HEAT TRANSFER   INTERNAL INTEGRALS   COEFFICIENTS

X =       .22797E+01 M =        .35700E+01 DELTA =  .45263E-01 HG =     0.             ZETA =    .26244E+00 CF =      .27229E-02
XL =      .32586E+01 TE =       .27902E+04 DELTH =  .30811E-05 QW =     0.             I4   =    .10541E-05 CH =    0.
Y =       .08985E+00 TW =       .52339E+04 DELT* =  .12336E-01 SUMQ =  0.              I5   =    .10184E-01 RETH =    .15575E+04
DY/DX =   .25137E+00 TAW =      .52339E+04 THETA =  .32271E-02 FORCE =  .17796E+03 I6   =    .13743E-05 REXL =    .15728E+07
                     DM/DX =    .47657E+00 PHI =    .48469E-07 LAT.F = 0.              I7   =    .10392E+00 REPH =    .23490E-01
                     UE =       .10307E+05 H =      .38226E+01                         I1P  =    .60260E-02 RED* =    .59539E+04
                     PE =       .37790E+03 DEL F =  .82318E+02 DEL I =  .17185E+01

CONTOUR PROPERTIES   FLOW PROPERTIES   BOUNDARY LAYER   HEAT TRANSFER   INTERNAL INTEGRALS   COEFFICIENTS

X =       .22818E+01 M =        .35715E+01 DELTA =  .45360E-01 HG =     0.             ZETA =    .26242E+00 CF =      .27224E-02
XL =      .32619E+01 TE =       .27898E+04 DELTH =  .30876E-05 QW =     0.             I4   =    .10529E-05 CH =    0.
Y =       .09044E+00 TW =       .52336E+04 DELT* =  .12367E-01 SUMQ =  0.              I5   =    .10182E-01 RETH =    .15574E+04
DY/DX =   .25113E+00 TAW =      .52336E+04 THETA =  .32333E-02 FORCE =  .17811E+03 I6   =    .13729E-05 REXL =    .15717E+07
                     DM/DX =    .47330E+00 PHI =    .45723E-07 LAT.F = 0.              I7   =    .10391E+00 REPH =    .23169E-01
                     UE =       .10309E+05 H =      .38247E+01                         I1P  =    .60230E-02 RED* =    [illegible]
                     PE =       .37440E+03 DEL F =  .82377E+02 DEL I =  .17197E+01

CONTOUR PROPERTIES   FLOW PROPERTIES   BOUNDARY LAYER   HEAT TRANSFER   INTERNAL INTEGRALS   COEFFICIENTS

X =       .22836E+01 M =        .35723E+01 DELTA =  .45407E-01 HG =     0.             ZETA =    .26241E+00 CF =      .27223E-02
XL =      .32635E+01 TE =       .27884E+04 DELTH =  .30904E-05 QW =     0.             I4   =    .10523E-05 CH =    0.
Y =       .09186E+00 TW =       .52335E+04 DELT* =  .12382E-01 SUMQ =  0.              I5   =    .10181E-01 RETH =    .15573E+04
DY/DX =   .27065E+00 TAW =      .52335E+04 THETA =  .32363E-02 FORCE =  .17818E+03 I6   =    .13722E-05 REXL =    .15774E+07
                     DM/DX =    .54453E+00 PHI =    .48749E-07 LAT.F = 0.              I7   =    .10390E+00 REPH =    .23490E-01
                     UE =       .10318E+05 H =      .38258E+01                         I1P  =    .60210E-02 RED* =    .59580E+04
                     PE =       .37593E+03 DEL F =  .81856E+02 DEL I =  .17608E+01
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CONTOUR PROPERTIES    FLOW PROPERTIES      BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS      COEFFICIENTS

                                                                                    ZETA =    .26241E+00 CF =     .27222E-02
X =      .22835E+01 M =      .35723E+01 DELTA =  .45410E-01 HG =     0.             I4   =    .10523E-05 CH =    0.
XL =     .32636E+01 TE =     .27883E+04 DELTB =  .38906E-05 QW =     0.             I5   =    .10181E-01 RETH =   .15573E+04
Y =      .99106E+00 TW =     .52335E+04 DELT* =  .12382E-01 SUMQ =   0.             I6   =    .13722E-05 REXL =   .15703E+07
DY/DX =  .25083E+00 TAW =    .52335E+04 THETA =  .32365E-02 FORCE =  .17819E+03     I7   =    .10390E+00 REPH =   .23457E-01
                    DM/DX =  .44359E+00 PHI =    .48750E-07 LAT.F =  0.             I1P  =    .68215E-02 RED* =   .59581E+04
                    UE =     .10310E+05 H =      .38258E+01
                    PE =     .37509E+03 DEL F =  .82416E+02 DEL I =  .17205E+01

CONTOUR PROPERTIES    FLOW PROPERTIES      BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS      COEFFICIENTS

                                                                                    ZETA =    .26241E+00 CF =     .27222E-02
X =      .22836E+01 M =      .35723E+01 DELTA =  .45411E-01 HG =     0.             I4   =    .10523E-05 CH =    0.
XL =     .32636E+01 TE =     .27883E+04 DELTB =  .38907E-05 QW =     0.             I5   =    .10181E-01 RETH =   .15573E+04
Y =      .99107E+00 TW =     .52333E+04 DELT* =  .12383E-01 SUMQ =   0.             I6   =    .13721E-05 REXL =   .15703E+07
DY/DX =  .28333E+00 TAW =    .52335E+04 THETA =  .32366E-02 FORCE =  .17819E+03     I7   =    .10390E+00 REPH =   .23457E-01
                    DM/DX =  .51163E+00 PHI =    .48751E-07 LAT.F =  0.             I1P  =    .68215E-02 RED* =   .59581E+04
                    UE =     .10310E+05 H =      .38259E+01
                    PE =     .37588E+03 DEL F =  .81752E+02 DEL I =  .17067E+01

CONTOUR PROPERTIES    FLOW PROPERTIES      BOUNDARY LAYER       HEAT TRANSFER       INTERNAL INTEGRALS      COEFFICIENTS

                                                                                    ZETA =    .26241E+00 CF =     .27222E-02
X =      .22836E+01 M =      .35724E+01 DELTA =  .45611E-01 HG =     0.             I4   =    .10523E-05 CH =    0.
XL =     .32637E+01 TE =     .27883E+04 DELTB =  .38907E-05 QW =     0.             I5   =    .10181E-01 RETH =   .15573E+04
Y =      .99108E+00 TW =     .52335E+04 DELT* =  .12383E-01 SUMQ =   0.             I6   =    .13721E-05 REXL =   .15703E+07
DY/DX =  .31567E+00 TAW =    .52335E+04 THETA =  .32366E-02 FORCE =  .17819E+03     I7   =    .10390E+00 REPH =   .23456E-01
                    DM/DX =  .60702E+00 PHI =    .48751E-07 LAT.F =  0.             I1P  =    .68214E-02 RED* =   .59581E+04
                    UE =     .10310E+05 H =      .38259E+01
                    PE =     .37587E+03 DEL F =  .81005E+02 DEL I =  .16911E+01
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THROAT RADIUS CORRECTED FOR DISPLACEMENT THICKNESS = .17819407E+00

TABLE OF NORMALIZED CONTOUR POINTS CORRECTED FOR DISPLACEMENT THICKNESS

DATA POINT	X	Y
1	-.40065563E+01	.32900550E+01
2	-.37126336E+01	.30896154E+01
3	-.34181920E+01	.28903452E+01
4	-.31235155E+01	.26912488E+01
5	-.28284830E+01	.24923573E+01
6	-.25337599E+01	.22936010E+01
7	-.22387808E+01	.20949276E+01
8	-.19437684E+01	.18963135E+01
9	-.16487376E+01	.16977170E+01
10	-.13537026E+01	.14991343E+01
11	-.10585835E+01	.13021613E+01
12	-.76347025E+00	.11511502E+01
13	-.66840388E+00	.10555792E+01
14	-.17335366E+00	.10075057E+01
15	.12172811E+00	.10035128E+01
16	.48527223E+00	.10590503E+01
17	.55082559E+00	.10764593E+01
18	.61132159E+00	.10947108E+01
19	.65008088E+00	.11074705E+01
20	.74271987E+00	.11415533E+01
21	.80915468E+00	.11690125E+01
22	.87559771E+00	.11969947E+01
23	.94169728E+00	.12248381E+01
24	.10078259E+01	.12526921E+01
25	.10740238E+01	.12805857E+01
26	.11403120E+01	.13085079E+01
27	.12067719E+01	.13364985E+01
28	.12735232E+01	.13646268E+01
29	.13405458E+01	.13928421E+01
30	.14080005E+01	.14212742E+01
31	.14759866E+01	.14499024E+01
32	.15446088E+01	.14787557E+01
33	.16139970E+01	.15078948E+01
34	.16863539E+01	.15374274E+01
35	.17559142E+01	.15674337E+01
36	.18280150E+01	.15980416E+01
37	.19035210E+01	.16293111E+01
38	.19807368E+01	.16616790E+01
39	.20597626E+01	.16946967E+01
40	.21411006E+01	.17290102E+01
41	.22262330E+01	.17648175E+01
42	.23151521E+01	.18022867E+01
43	.24085230E+01	.18417200E+01
44	.26537586E+01	.19456754E+01
45	.29174552E+01	.20581817E+01
46	.32047224E+01	.21742738E+01
47	.35108341E+01	.23048205E+01
48	.38260120E+01	.24290864E+01
49	.41626745E+01	.25059712E+01
50	.43921648E+01	.26654751E+01
51	.46394414E+01	.27032800E+01
52	.48970450E+01	.29177405E+01
53	.51477088E+01	.30621850E+01
54	.54264405E+01	.31952613E+01
55	.56760680E+01	.33109146E+01
56	.59088207E+01	.34053078E+01

57	.61384297E+01	.34883482E+01
58	.63605332E+01	.35619973E+01
59	.65870779E+01	.36344100E+01
60	.68191835E+01	.37093644E+01
61	.70600722E+01	.378989[illegible]2E+01
62	.72941236E+01	.38702844E+01
63	.75391916E+01	.39559108E+01
64	.77885102E+01	.40636574E+01
65	.80431565E+01	.41330677E+01
66	.83022048E+01	.42227261E+01
67	.85639195E+01	.43115802E+01
68	.88206653E+01	.43956009E+01
69	.90840386E+01	.44719876E+01
70	.93188483E+01	.45480945E+01
71	.95729819E+01	.46217470E+01
72	.98368008E+01	.46942770E+01
73	.10091833E+02	.47660129E+01
74	.10344717E+02	.483481[illegible]7E+01
75	.10617606E+02	.49076361E+01
76	.10890398E+02	.49811465E+01
77	.11158316E+02	.5053708[illegible]E+01
78	.11461127E+02	.51304872E+01
79	.11727866E+02	.5208[illegible]4E+01
80	.11994298E+02	.52743500E+01
81	.12277050E+02	.53535728E+01
82	.12557405E+02	.54259402E+01
83	.12698832E+02	.54614418E+01
84	.12769177E+02	.54792361E+01
85	.12894618E+02	.54877421E+01
86	.12872282E+02	.54920313E+01
87	.12832818E+02	.54946142E+01
88	.12831587E+02	.54942908E+01
89	.128[illegible]3924E+02	.54949021E+01
90	.128[illegible]6080E+02	.54955425E+01

SUMMARY OUTPUT FROM TRL MODULE

A/A*	DELTA ISP(TBL)
2.00000	.24070
4.00000	.48403
6.00000	.65864
10.00000	.74468
20.00000	1.30432
30.00000	1.68439
30.03857	1.69149

SUMMARY OF RESULTS FROM SPP COMPUTER PROGRAM   VERSION 1.1 DATED 31 JAN75

CASE TITLE EXTENDED DELTA VALIDATION CASE

**** VACUUM PERFORMANCE ****

NOTE	LOSS MECHANISM	ETA CALC	ETA EMPIR	ETA INPUT	ETA SELECTED	METHOD SELECTED
	KINETIC	1.0000	.9939	1.0000	.9939	E
1	2D-2DH	.9478	.9451	1.0000	.9478	C
2	COMB EFF	.9843	.9735	1.0000	.9843	C
3	SUBMERG	1.0000	.9921	1.0000	.9921	E
4	2-D	1.0000	.9742	1.0000	1.0000	C
PRODUCT OF ETAS		.9329	.9212	1.0000	.9199	

TURBULENT BOUNDARY LAYER LOSS DECREMENTS

METHOD	DELTA ISP(LBF-SEC/LBM)	
CALCULATED	1.6844	
EMPIRICAL	1.7367	
INPUT	0.0000	
VALUE SELECTED	1.6844	METHOD SELECTED C

DELIVERED VACUUM SPECIFIC IMPULSE (LBF-SEC/LBM)

METHOD	ISP(VAC)D
CALCULATED	287.5828
EMPIRICAL	283.9066
INPUT	310.0770
VALUE SELECTED	283.5560

ISP DECREMENT DUE TO EXHAUSTING TO AMBIENT PRESSURE

AVE. AMBIENT PRESSURE(PSIA)	.0971
AVE. CHAMBER PRESSURE(PSIA)	[illegible]
AVE. EXPANSION RATIO	[illegible]
DISCHARGE COEFF.	1.0113
DELTA ISP (LBF-SEC/LBM)	.8342

ISP DELIVERED TO THE AVERAGE AMBIENT PRESSURE OF   .09714 PSIA IS = 282.7210 LBF-SEC/LBM

THRUST - TIME HISTORY

TIME	A/A*	F-VAC	PA*AE	F-DFL	I-VAC	DEL-I	I-DFL	MDOT	MDOT-INT	F-INT
0.00	30.09	13331.	35.	13296.	284.99	.74	284.25	46.775	0.00	0.0
2.00	30.00	13555.	35.	13519.	284.93	.74	284.18	47.572	94.35	26815.2
4.00	29.91	13778.	36.	13742.	284.86	.74	284.12	48.369	190.29	54076.9
6.00	29.79	13567.	37.	13530.	284.73	.77	283.96	47.647	286.30	81349.1
8.00	29.66	13439.	37.	13401.	284.59	.79	283.79	47.222	381.17	108280.1
10.00	29.56	13095.	38.	13057.	284.42	.83	283.59	46.041	474.44	134738.3
12.00	29.43	12847.	39.	12806.	284.27	.86	283.41	45.194	565.67	160603.4
14.00	29.31	12908.	40.	12869.	284.15	.87	283.28	45.398	656.26	186272.1
16.00	29.19	13475.	40.	13435.	284.11	.85	283.26	47.431	749.09	212567.7
18.00	29.08	13499.	41.	13458.	284.00	.86	283.14	47.530	844.05	239460.5
20.00	28.96	13691.	41.	13649.	283.90	.85	283.05	48.273	939.81	266567.6
22.00	28.85	14100.	41.	14059.	283.84	.83	283.00	49.677	1037.71	294275.8
24.00	28.74	14559.	42.	14518.	283.77	.81	282.96	51.307	1138.69	322852.4
26.00	28.62	14866.	42.	14822.	283.69	.80	282.89	52.396	1242.39	352192.6
28.00	28.50	15271.	42.	15229.	283.62	.78	282.84	53.843	1346.63	382243.8
30.00	28.39	15650.	42.	15608.	283.54	.76	282.79	55.196	1457.67	413081.0
32.00	28.27	15896.	42.	15854.	283.45	.75	282.69	56.083	1568.95	444543.4
34.00	28.16	16060.	42.	16019.	283.35	.75	282.60	56.681	1681.71	476415.5
36.00	28.05	16198.	43.	16156.	283.24	.75	282.50	57.189	1795.58	508589.3
38.00	27.93	16259.	43.	16216.	283.14	.74	282.39	57.423	1910.20	540960.[illegible]
40.00	27.83	16346.	43.	16309.	283.03	.74	282.29	57.753	2025.37	573479.8
42.00	27.72	16158.	43.	16115.	282.91	.75	282.16	57.113	2140.24	605897.9
44.00	27.67	14869.	43.	14826.	282.67	.82	281.85	52.602	2249.95	636439.5
46.00	27.60	5081.	43.	5038.	278.91	2.37	276.54	18.219	2320.77	656702.4
48.00	27.60	1391.	43.	1348.	252.87	7.85	245.02	5.502	2344.49	663098.6
50.00	27.60	161.	43.	117.	220.91	59.46	161.45	.727	2350.72	664556.[illegible]
52.00	27.60	56.	43.	10.	225.40	181.93	43.46	.237	2351.69	664681.6

AVE. ISP= 282.64 LBF-SEC/LBM AVE. MDOT= 45.22 LBM/SEC

$$$$$$$$$$ FINAL EXECUTION TIME THIS CASE = 1.180 (MIN) $$$$$$$$$$

Sample Case Number 2

Input Listing

```
TITLE EXTENDED DELTA VALIDATION CASE
GEOM
 $GEOM
 ASUB(1)=2.38,   NASUB=1,
 THALL=4,
 EPHAT=2.38,
 ASUP(1)=2,4,6,10,2.,30,
 NASUP=6,
 THE=16,
 THETA=23,
 THETA1=36,
 RCURV=2,
 RST=2.141,
 ZC(2)= 1.791462,1.5,2.5,3.5,4.5,
 5.521,6.65577,8.68753,10.626,12.795623,
 RC(2)=1.3712274,1.46709,1.888466,2.312961,2.7374156,
 3.2695,3.6933,4.39516,4.96767,5.553246147,
 N.S=11,
 $END
TRAJECTORY
 $TRAJ
 RAMAT(1)=.08,.095,.098,.1,.1,
 TTRJ(1)=0.,18.,32.,44.,100.,
 NTRJPT=5,
 $END
PROBLEM
 $PROB
 ANK=1,   IREQ=1,
 $END
REACTANTS
N 1.     H 4.     CL 1.0   O 4.0                .70     -70690. S 298.15
AL 1.0                                          .16     0.0     S 298.15
C 7.319  H 10.909 O  0.092                      .14     11700.  S 298.15

NAMELISTS
 $ODE
 EPRAT=2.38,
 P(1)=541,
 RSTAR=T,
 SWT=T,
 N.PRNT=F,
 ENCT=T,
 MI(1)= 30.,DFSKED(1)=100.,
 $END
```

```
REACTIONS
 CO + O  =     CO2   , A=5.05E15,  N=0,   ,  H=2.5,                     BAULCH (1968)L)
 CL2     =  CL + CL  , A=2.E13,    N=0,   ,  H=66.650,                  SOLOMON(1971)
 HCL     =   H + CL  , A=6.86E22,  N=2,   ,  H=102.17,                  JACOBS (1966)
 HO2     =   H + O2  , A=2.40E15,  N=0.0 ,   H=45.9 ,            NO.36 BAULCH (1969)
 H2      =    H + H  , A=7.00E12,  N=-.50,   H=92.60,            NO.3 BROKAW   (1970)
 H + OH  =      H2O  , A=3.00E19,  N=1.00,   H= 0.00,            NO.5  PREHN   (1967)
 O2      =    O + O  , A=2.95E13,  N=1.00,   H=118.7,            NO.1 JOHNSTON (1968)
  ALCL+ CL    = ALCL2        , A=3.0E16  ,N= 0.5   ,B= 0.0    ,              31
  ALCL2+CL    = ALCL3        , A=3.0E16  ,N= 0.5   ,B= 0.0    ,              32
  ALCL+ O     = ALOCL        , A=3.0E16  ,N= 0.5   ,B= 0.0    ,              41
AL + H = ALH ,        A=  3.0E16 , N=  0.5 , H=  0.0, ESTIMATE
H + ALO2 = ALO2H ,    A=  3.0E16 ; N=  0.5 , H=  0.0, ESTIMATE
OH + ALO = ALO2H ,    A=  3.0E16 , N=  0.5 , H=  0.0, ESTIMATE
ALO + H = ALOH ,      A=  3.0E16 , N=  0.5 , H=  0.0, ESTIMATE
END THR REAX
 CO +CLO = CO2 + CL  , A=1.E11  ,  N=-.5 ,  H=3.5,                      ESTIMATE
 CO + O  =     CO2   , A=1.78E10,  N=0,   ,  H=2.53,                    BAULCH (1968)L)
 CO + OH = CO2 + H   , A=5.6E11 ,  N=0,   ,  H=1.08,                    BAULCH (1968)L)
CO2 + H2 =  CO +H2O  , A=9.5E8  ,  N=-.5 ,   H=15.,                     TUNDER (1967)
 CO2+ O  = CO  + O2  , A=1.9E13 ,  N=0,   ,  H=54.15,                   BAULCH (1968)L)
 CL + HO2= CLO + OH  , A=5.E11  ,  N=-.5 ,   H=3.5,                     ESTIMATE
 CL + HO2= HCL + O2  , A=5.E11  ,  N=-.5 ,   H=2.4,                     ESTIMATE
 CL + H2 = HCL + H   , A=1.2E13,   N=0,   ,  B=4.3,                     WESTONBERG (68
 CL + OH = HCL + O   , A=2.0E11,   N=-.67,   H=.1    ,                  MAYER  (1967)
 CLO+ H  = HCL + O   , A=5.E11  ,  N=-.5 ,   H=3.54,                    ESTIMATE
 CLO+ O  =  CL + O2  , A=5.E11  ,  N=-.5 ,   H=3.54,                    ESTIMATE
CL2 + H  = HCL + CL  , A=3.0E14,   N=0,   ,  H=3.0,                     CHERRY (1967)
CL2 + O  = CLO + CL  , A=5.E11  ,  N=-.5 ,   H=3.2,                     ESTIMATE
 HCL + OH= H2O + CL  , A=1.0E11,   N=-.5 ,   H=6.0   ,                  CHERRY (1967)
 H2 + O  =   H + OH  , A=2.96E13,  N=0.00,   H= 9.80,            NO.19 BRABBS  (1970)
 H2 + OH =   H + H2O , A=2.19E13,  N=0.00,   H= 5.15,            NO.20 BAULCH  (1968)
 NO + NO =  N2 + O2  , A=1.E13  ,  N=0,   ,  H=76.0,                    BAULCH (1967)L)
 O + OH  =  O + H2O  , A=5.75E12,  N=0.00,   H= 0.78,            NO.21 BAULCH  (1969)
 O2 + H  =    OH + O , A=1.46E14,  N=0.00,   H=16.40,            NO.18 BELLES  (1970)
  ALO   + CO     = AL    + CO2   ,A=1.0E11,N=-.5      ,B= 3.215 ,            217
  ALO   + O      = AL    + O2    ,A=5.3 E11,N=-.5     ,B= 3.215 ,            220
  AL2O  + CL     = AL    + ALOCL,A=1.0E11,N=-.5       ,B= 3.521 ,            221
  AL    + OH     = ALO   + H     ,A=5.3 E11,N=-.5     ,B= 2.092 ,            226
  ALO   + ALCL   = AL2O  + CL    ,A=1.0E11,N=-.5      ,B= 3.243 ,            229
  ALCL2+ H       = ALCL  + HCL   ,A=1.0E11,N=-0.5     ,B=2.544    ,          232
  AL    + CL2    = ALCL  + CL    ,A=5.3 E11,N=-0.5    ,B=1.6      ,          235
  AL    + HCL    = ALCL  + H     ,A=5.3 E11,N=-0.5    ,B=2.859    ,          236
  ALO   + CL     = ALCL  + O     ,A=5.3 E11,N=-0.5    ,B=2.859    ,          237
  ALO   + ALCL2  = ALCL  + ALOCL,A=1.0E11,N=-0.5      ,B=2.544    ,          240
  ALCL  + CL2    = ALCL2 + CL    ,A=1.0E11,N=-0.5     ,B=1.6      ,          242
  ALCL  + CO2    = ALOCL + CO    ,A=1.0E11,N=-0.5     ,B=1.574    ,          243
  ALCL2+ OH      = ALOCL + HCL   ,A=1.75E11,N=-0.5    ,B=27.683 ,            244
  ALO   + CL2    = ALOCL + CL    ,A=1.0E11,N=-0.5     ,B=1.6      ,          245
  ALCL2+ O       = ALOCL + CL    ,A=1.0E11,N=-0.5     ,B=2.544    ,          246
  ALO   + HCL    = ALOCL + H     ,A=1.0E11,N=-0.5     ,B=2.859    ,          247
  ALCL  + OH     = ALOCL + H     ,A=1.0E11,N=-0.5     ,B=2.859    ,          248
  ALCL  + O2     = ALOCL + O     ,A=1.0E11,N=-0.5     ,B=3.296    ,          249
  ALCL2+ ALCL2   = ALCL  + ALCL3,A=1.0E11,N=-0.5      ,B=2.544    ,          306
  ALCL2+ CL2     = ALCL3 + CL    ,A=1.0E11,N=-0.5     ,B=1.6      ,          311
  ALCL3+ H       = ALCL2 + HCL   ,A=1.0E11,N=-0.5     ,B=2.591    ,          318
```

```
ALO + OH = ALO2 + H .          A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALO + CLO = ALO2 + CL .        A=  1.0E11 , N= -0.5 , B=  3.5365, ESTIMATE
ALO + O2 = ALO2 + O .          A=  1.0E11 , N= -0.5 , B=  6.552 , ESTIMATE
ALO + HO2 = ALO2 + OH .        A=  1.0E11 , N= -0.5 , B=  3.6025, ESTIMATE
ALO2 + H2 = H + ALO2H .        A=  1.0E11 , N= -0.5 , B=  5.731 , ESTIMATE
ALO2 + OH = O + ALO2H .        A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALO2 + HCL = CL + ALO2H .      A=  1.0E11 , N= -0.5 , B=  5.6705, ESTIMATE
ALOH + O2 = O + ALO2H .        A=  1.0E11 , N= -0.5 , B=  6.556 , ESTIMATE
ALOH + OH = H + ALO2H .        A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALOH + CLO = CL + ALO2H .      A=  1.0E11 , N= -0.5 , B=  3.5365, ESTIMATE
AL + H2O = ALOH + H .          A=  5.0E11 , N= -0.5 , B=  7.0015, ESTIMATE
ALO + H2 = ALOH + H .          A=  1.0E11 , N= -0.5 , B=  5.731 , ESTIMATE
ALO + HCL = ALOH + CL .        A=  1.0E11 , N= -0.5 , B=  5.6705, ESTIMATE
ALO + OH = ALOH + O .          A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
ALH + H = AL + H2 .            A=  5.0E11 , N= -0.5 , B=  3.76  , ESTIMATE
ALH + OH = AL + H2O .          A=  1.0E11 , N= -0.5 , B=  3.76,   ESTIMATE
ALH + O  = AL + OH .           A=  5.0E11 , N= -0.5 , B=  3.76,   ESTIMATE
ALH + CL = AL + HCL .          A=  5.0E11 , N= -0.5 , B=  3.76,   ESTIMATE
 AL + ALCL2=ALCL +ALCL, A=5.0E11,N=-0.5,B=6.1500,              ESTIMATE
LAST REAC
THIRD BODY REAC RATE RATIOS
ALL EQUAL 1.0
LAST CARD
 $RDK
 TEXPLIN=0.,  JPRNT=-2,  FOREL=1.E-4,
 $END
```

```
TITLE EXTENDED DELTA VALIDATION CASE
BEAM
 $BEAM
 ACUA(1)=2,30,   VASUR=1,
 T,ALL=A,
 FCWAT=2,30,
 ACUP(1)=2,4,6,10,20,30,
 VIS.IP=A,
 THE=16,
 THETA=23,
 THETA1=30,
 DRUAVE=2,
 DE(=2,101,
 ZS(2)= 1,281662,1,5,2,5,3,5,4,5,
 5,521,6,65577,8,54753,10,424,12,705423,
 DS(2)=1,3712276,1,64300,1,888666,2,317941,2,7374156,
 3,2605,3,6833,4,39914,4,34261 5,5532461670
 N,S=11,
 $END
TRAJECTORY
 $TRAJ
 DAMAT(1)=.08,.095,.098,.1,.1,
 TTRJ(1)=0,.10,.32,.66,.100,.
 NTJDT=6,
 $END
PROBLEM
 $ODE
 ODE=1,   IREO=1,
 $END
REACTANTS
N 1.      H 4.      CL 1.0   O 4.0               .70     -70400. S 298.15
AL 1.0                                          .14     0.0     S 298.15
C 7.310  H 10.509 O  0.003                      .16     11700.  S 298.15

NAMELISTS
 $ODE
 FCWAT=2,30,
 P(1)=6541,
 DETA=1,
 DT=T,
 N,DENT=F,
 FACT=T,
 WT(1)=100,DESRF(1)=100,
 $END
REACTIONS
 [illegible]
 FCL + ALOCL  = ALCL2  ,  AT 9,0F16 , ...  0,5 , ...   EST IMATE
 [illegible]
END TM  REAC
 [illegible]
```

```
COZ+ H  = CO  + O2 , A=1.3E13 ,  N=0.  ,  E=54.14,              BAULCH (1968)L1
CL + HO2 = CLO + OH , A=5.E11  ,  N=-.5 ,  E=3.5,                ESTIMATE
CL + HO2 = HCL + O2 , A=5.E11  ,  N=-.5 ,  E=2.6,                ESTIMATE
CL + H2 = HCL + H   , A=1.2E13,   N=0.  ,  E=4.3,                WESTONBERG (68
CL + OH = HCL + O   , A=2.0E11,   N=-.67,  E=.1 ,                MAYER  (1967)
CLO + H = HCL + O   , A=5.E11  ,  N=-.5 ,  E=3.56,               ESTIMATE
CLO + O = CL + O2   , A=5.E11  ,  N=-.5 ,  E=3.56,               ESTIMATE
CL2 + H = HCL + CL  , A=3.0E14,   N=0.  ,  E=3.0,                CHERRY (1967)
CL2 + O = CLO + CL  , A=5.E11  ,  N=-.5 ,  E=3.2,                ESTIMATE
HCL + OH = H2O + CL , A=1.0E11,   N=-.5 ,  E=6.0 ,               CHERRY (1967)
H2 + O =  H + OH    , A=2.24E13,  N=0.00,  E= 9.80,          NO.19 BRABBS  (1970)
H2 + OH = H + H2O   , A=2.19E13,  N=0.00,  E= 5.15,          NO.20 BAULCH  (1968)
HO + HO = H2 + O2   , A=1.E13  ,  N=0.  ,  E=76.0,                BAULCH (1968)L4
H + O2 =  O + OH    , A=5.75E12,  N=0.00,  E= 0.70,          NO.21 BAULCH  (1968)
O2 + M =  O + O     , A=1.66E14,  N=0.00,  E=14.80,          NO.18 BELLES  (1973)
AL0 + CO    = AL   + CO2  ,A=1.0E11,N=-.5    ,B= 3.215 ,            217
AL0 + O     = AL   + O2   ,A=5.3 E11,N=-.5   ,B= 3.215 ,            220
AL20 + CL   = AL   + ALOCL,A=1.0E11,N=-.5    ,B= 3.421 ,            221
AL  + OH    = ALO  + H    ,A=5.3 E11,N=-.5   ,B= 2.892 ,            226
AL0 + ALCL  = AL20 + CL   ,A 1.0E11,N=-.5    ,B= 3.267 ,            229
ALCL2+ H    = ALCL + HCL  ,A=1.0E11,N=-0.5   ,B=2.566  ,            232
AL  + CL2   = ALCL + CL   ,A=5.3 E11,N=-0.5  ,B=1.6    ,            235
AL  + HCL   = ALCL + H    ,A=5.3 E11,N=-0.5  ,B=2.853  ,            236
AL0 + CL    = ALCL + O    , =5.3 E11,N=-0.5  ,B=2.853  ,            237
AL0 + ALCL2 = ALCL + ALO  ,A=1.0E11,N=-0.5   ,B=2.566  ,            260
ALCL + CL2  = ALCL2 + CL  ,A= .0E11,N=-0.5   ,B=1.6    ,            262
ALCL + CO2  = ALOCL + CO  ,A=1.0E11,N=-0.5   ,B=3.520  ,            263
ALCL2+ OH   = ALOCL + HCL ,A=.17E11,N=-0.5   ,B=27.683 ,            264
AL0 + CL2   = ALOCL + CL  ,A=1.0E11,N=-0.5   ,B=1.6    ,            265
ALCL2+ O    = ALOCL + CL  ,A=1.0E11,N=-0.5   ,B=2.566  ,            266
AL0 + HCL   = ALOCL + H   ,A=1.0E11,N=-0.5   ,B=2.853  ,            267
ALCL + OH   = ALOCL + H   ,A=1.0E11,N=-0.5   ,B=2.853  ,            268
ALCL + O2   = ALOCL + O   ,A=1.0E11,N=-0.5   ,B=3.234  ,            269
ALCL2+ ALCL2 = ALCL + ALCL3,A=1.0E11,N=-0.5  ,B=2.566  ,            306
ALCL2+ CL2  = ALCL3 + CL  ,A=1.0E11,N=-0.5   ,B=1.6    ,            311
ALCL2+ H    = ALCL2 + HCL ,A=1.0E11,N=-1.5   ,B=2.901  ,            314
AL0 + OH = AL02 + H ,      A=  1.0E11 , N= -0.5 , B=  5.6265  ESTIMATE
AL0 + CLO = AL02 + CL ,    A=  1.0E11 , N= -0.5 , B=  3.5165, ESTIMATE
AL0 + O2 = AL02 + O ,      A=  1.0E11 , N= -0.5 , B=  6.552 , ESTIMATE
AL0 + HO2 = AL02 + OH ,    A=  1.0E11 , N= -0.5 , B=  3.6425, ESTIMATE
AL02 + H2 = H + AL02H ,    A=   .0E11 , N= -0.5 , B=  5.931 , ESTIMATE
AL02 + OH = O + AL02H ,    A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
AL02 + HCL = CL + AL02H ,  A=   .0E11 , N= -0.5 , B=  5.6765, ESTIMATE
AL0H + H2 = O + AL02H ,    A=  1.0E11 , N= -0.5 , B=  5.656 , ESTIMATE
AL0H + OH = H + AL02H ,    A=  1.0E11 , N= -0.5 , B=  5.6265, ESTIMATE
AL0H + CLO = CL + AL02H ,  A=  1.0E11 , N=  0.5 , B=  3.5165, ESTIMATE
AL + H2O = AL0H + H ,      A=  5.0E11 , N= -0.5 , B=  3.0015, ESTIMATE
AL0 + H2 = AL0H + H ,      A=  1.0E11 , N= -0.5 , B=  5.931 , EST
AL0 + HCL = AL0H + CL ,    A=  1.0E11 , N= -0.5 , B=  5.6765, E
AL0 + OH = AL0H + O ,      A=  1.0E11 , N= -0.5 , B=  5.6265,
AL + H = AL + H2 ,         A=  5.0E11 , N= -0.5 , B=  3.0   , ESTI
AL + OH = AL + H2O ,       A=  1.0E11 , N= -0.5 , B=  3.700   ESTIM
AL + O = AL + OH ,         A=  5.0E11 , N= -0.5 , B=  3.700   ESTIM TE
AL + CL = AL + HCL ,       A=  5.0E11 , N= -0.5 , B=  3.700   ESTIMATE
AL + S CL2=ALCL +ALCL, A=5, E11, N=-.5, 1500,               ESTIMATE
LAST READ
THIRD BODY READ RATE RATIOS
ALL EQUAL 1.0
LAST CARD
 DONE
 TRODUTION,  1000TO02, FREEL01 FO0,
 0003
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$$$$$$$$$$ CURRENT EXECUTION TIME THIS CASE =        .165  (MIN) $$$$$$$$$$

REACTIONS
 CO + O  =    CO2   . A=5.05E15,  N=0.  .  E=2.5.                    BAULCH (1968)L)
 CL2     =  CL + CL . A=2.E13,    N=0.  .  E=48.480.                 SOLOMON(1971)
 HCL     =   H + CL . A=4.46E21,  N=2.  .  E=102.17.                 JACOBS (1966)
 HO2     =   H + O2 . A=2.40E15,  N=0.0 .  E=45.0 .            NO.34 BAULCH (1969)
 H2      =    H + H . A=2.2E12,   N=-.5.  E=92.60.              NO.3 BROKAW  (1974)
 H + OH  =      H2O . A=7.0E19,   N=1.00, E= 0.00.              NO.5 BREHN   (1967)
 O2      =    O + O . A=2.85E19,  N=1.00, E=118.7.              NO.1 JOHNSTON (1963)
  ALCL+ CL   = ALCL2          . A=3.0E14  ,N= 0.5   ,E= 0.0   .                31
  ALCL2+CL   = ALCL3          . A=3.0E14  ,N= 0.5   ,E= 0.0   .                32
  ALCL+ O    = ALOCL          . A=3.0E16  ,N= 0.5   ,E= 0.0   .                41
AL + H = ALH .        A=  3.0E14 . N=  0.5 . E=  0.0. ESTIMATE
H + ALO2 = ALO2H .    A=  3.0E14 . N=  0.5 . E=  0.0. ESTIMATE
OH + ALO = ALO2H .    A=  3.0E14 . N=  0.5 . E=  0.0. ESTIMATE
ALO + H = ALOH .      A=  3.0E14   N=  0.5 . E=  0.0. ESTIMATE
END FOR HEAT
 CO +CL2 = CO2 + CL . A=1.E11     N=-.5 .  E=3.5.                    ESTIMATE
 CO + O  =     CO2  . A=1.78E10,  N=0.  .  E=2.83.                   BAULCH (1968)L)
 CO + OH = CO2 + H  . A=5.6E11 .  N=0.  .  E=1.08.                   BAULCH (1968)L)
CO2 + H2 = CO +H2O  . A=9.5E4     N=-.5 .  E=15..                    TUNDER (1967)
 CO2+ O  = CO  + O2 . A=1.0E13 .  N=0.  .  E=54.15.                  BAULCH (1968)L)
 CL + H2O= CLO + OH . A=5.E11  .  N=-.5 .  E=3.5.                    ESTIMATE
 CL + H2O= HCL + O2 . A=5.E11  .  N=-.5 .  E=2.4.                    ESTIMATE
 CL + H2 = HCL + H  . A=1.2E13.   N=0.  .  E=4.3.                    WESTONBERG (AF
 CL + OH = HCL + O  . A=2.0E12.   N=-.47,  E=.1   .                  MAYER  (1967)
 CLO+ H  = HCL + O  . A=5.E11  .  N=-.5 .  E=3.56.                   ESTIMATE
 CLO+ O  =  CL + O2 . A=5.E11  .  N=-.5 .  E=3.56.                   ESTIMATE
CL2 + H  = HCL + CL . A=3.0E14.   N=0.  .  E=3.0.                    CHERRY (1967)
CL2 + O  = CLO + CL . A=5.E11     N=-.5 .  E=3.2.                    ESTIMATE
 HCL + OH= H2O + CL . A=1.0E11.   N=-.5 .  E=5.0   .                 CHERRY (1967)
 H2 + O  =   H + OH . A=2.8E11.   N=0.00,  E= 9.00.             NO.16 BRABBS  (1970)
 H2 + OH =  H + H2O . A=2.19E13.  N=0.00,  E= 5.15.             NO.20 BAULCH  (1968)
 HO + H2 = H2 + O2  . A=1.E13     N=0.  .  E=76.0.                   BAULCH (1969)L4
 OH + OH = O + H2O  . A=5.75E12.  N=0.00,  E= 0.78.             NO.21 BAULCH  (1968)
 O2 + H  =  OH + O  . A=1.66E14.  N=0.00,  E=16.40.             NO.18 BELLES  (1970)
  ALO  + CO    = AL    + CO2   .A=1.0E11,N=-.5    ,E= 3.215 .                217
  ALO  + O     = AL    + O2    .A=5.3 E11,N=-.5   ,E= 3.215 .                220
  ALO2 + CL    = AL    + ALOCL .A=1.0E11,N=-.5    ,E= 1.421 .                221
  AL   + OH    = ALO   + H     .A=5.3 E11,N=-.5   ,E= 2.432 .                224
  ALO  + ALCL  = AL2O  + CL    .A=1.0E11,N=-.5    ,E= 3.269 .                225
  ALCL2+ H     = ALCL  + HCL   .A=1.0E11,N=-0.5   ,E=2.566  .                233
  AL   + CL2   = ALCL  + CL    .A=5.3 E11,N=-0.5  ,E=1.4    .                235
  AL   + HCL   = ALCL  + H     .A=5.3 E11,N=-0.5  ,E=2.851  .                236
  ALO  + CL    = ALCL  + O     .A=5.3 E11,N=-0.5  ,E=2.851  .                237
  ALO  + ALCL2 = ALCL  + ALOCL .A=1.0E11,N=-0.5   ,E=2.566  .                240
  ALCL + CL2   = ALCL2 + CL    .A=1.0E11,N=-0.5   ,E=1.4    .                242
  ALCL + CO2   = ALOCL + CO    .A=1.0E11,N=-0.5   ,E=3.420  .                243
  ALCL2+ OH    = ALOCL + HCL   .A=1.7E11,N=-0.5   ,E=7.493  .                244
  ALO  + CL2   = ALOCL + CL    .A=1.0E11,N=-0.5   ,E=1.4    .                245
  ALCL2+ O     = ALOCL + CL    .A=1.0E11,N=-0.5   ,E=2.566  .                246
  ALO  + HCL   = ALOCL + H     .A=1.0E11,N=-0.5   ,E=2.851  .                247
  ALCL + OH    = ALOCL + H     .A=1.0E11,N=-0.5   ,E=2.851  .                248
  ALCL + O2    = ALOCL + O     .A=1.0E11,N=-0.5   ,E=3.236  .                249
  ALCL2+ ALCL2 = ALCL  + ALCL3 .A=1.0E11,N=-0.5   ,E=2.566  .                306
  ALCL2+ CL2   = ALCL3 + CL    .A=1.0E11,N=-0.5   ,E=1.4    .                311
  ALCL3+ H     = ALCL2 + HCL   .A=1.0E11,N=-0.5   ,E=2.571  .                318
ALO + OH = ALO2 + H .       A=  1.0E11 . N= -0.5 . E=  5.4265. ESTIMATE
ALO + CLO = ALO2 + CL .     A=  1.0E11 . N= -0.5 . E=  3.6365. ESTIMATE
ALO + O2 = ALO2 + O .       A=  1.0E11 . N= -0.5 . E=  4.442 . ESTIMATE
ALO + H2O = ALO2 . H2 .     A=  1.0E11 . N= -0.5 . E=  3.4425. ESTIMATE
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TITLE EXTENDED DELTA VALIDATION CASE
GEOM
TRAJECTORY
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TRAJECTORY INFORMATION

TIME(SEC)	P-AMB(PSIA)
0.	.600000E-01
18.0000	.950000E-01
32.0000	.980000E-01
46.0000	.100000
100.000	.100000

PROBLEM

```
     ZONE=    1
REACTANTS
N   1.0000  H   4.0000  CL  1.0000  O   4.0000     -0.0000     .700000     -70690.09  S   298.150     -0.00000
AL  1.0000     -0.0000     -0.0000     -0.0000     -0.0000     .160000          0.00  S   298.150     -0.00000
C   7.3190  H  10.5090  O    .0990     -0.0000     -0.0000     .140000      11700.00  S   298.150     -0.00000
NAMELISTS

     NO SOME VALUE GIVEN FOR OF, FORAT, FA, OR FPCT

SPECIES BEING CONSIDERED IN THIS SYSTEM
     J12/65  AL(S)          J12/65  AL(L)          J12/65  AL             J 6/70  ALCL           J 9/64  ALCL2
     J 6/70  ALCL3(S)       J 6/70  ALCL3(L)       J 6/70  ALCL3          J 6/63  ALH            J12/62  ALN(S)
     J 3/67  ALN            J 6/70  ALO            J 9/64  ALOCL          J12/67  ALOH           J12/68  ALO2
     J12/68  ALO2H          J 6/70  AL2CL6         J 9/65  AL2O           J 9/65  AL2O2          J 3/66  AL2O3(S)
     J 3/66  AL2O3(L)       J 3/61  C(S)           J 3/61  C              J12/69  CCL            J12/68  CCL2
     J 6/70  CCL3           J12/68  CCL4           J12/67  CH             J 6/69  CH2            J 3/61  CH2O
     J 6/69  CH3            J 3/61  CH4            J 6/69  CN             J 6/66  CNN            J12/70  CN2
     J 9/65  CO             J12/65  COCL           J 6/61  COCL2          J 9/65  CO2            J12/69  C2
     J12/68  C2CL2          J 3/67  C2H            J 3/61  C2H2           J 9/65  C2N            J 3/67  C2N
     J 3/61  C2N2           J 9/66  C2O            J12/69  C3             J 6/68  C3O2           J12/69  C4
     J12/69  C5             J 3/61  CL             J 6/66  CLCN           J 6/61  CLO            J 3/61  CLO2
     J 9/65  CL2            J12/65  CL2O           J 9/65  H              J 3/64  HALO           J 9/64  HCL
     J12/69  HCN            J12/70  HCO            J12/70  HNCO           J 3/63  HNO            J 3/64  HO2
     J 3/61  H2             L11/65  H2O(S)         L11/65  H2O(L)         J 3/61  H2O            L 2/69  H2O2
     J 3/61  N              J12/70  NCO            J12/65  NH             J12/65  NH2            J 9/65  NH3
     J 6/63  NO             J12/65  NOCL           J 9/64  NO2            J12/65  NO2CL          J 9/65  N2
     J12/65  N2H4           J12/64  N2O            J 9/64  N2O4           J12/70  N3             J 6/62  O
     J12/70  OH             J 9/65  O2             J 6/61  O3

OF =    0.000000
                              EFFECTIVE FUEL        EFFECTIVE OXIDANT          MIXTURE
ENTHALPY                         HPP(2)                 HPP(1)                   HSUB0
(KG-MOL)(DEG K)/KG          -.20370968E+03          0.                      -.20370968E+03

KG-ATOMS/KG                     BOP(I,2)                BOP(I,1)                  BO(I)
          N                  .59579955E-02          0.                       .59579955E-02
          H                  .30531905E-01          0.                       .30531905E-01
          CL                 .59579955E-02          0.                       .59579955E-02
          O                  .23307463E-01          0.                       .23307463E-01
          AL                 .59299801E-02          0.                       .59299801E-02
          C                  .10237746E-01          0.                       .10237746E-01

IT       N        H       CL        O       AL        C
 1  -13.330   -9.300  -22.270  -19.006  -13.132  -11.667   13.000
 1  -13.036   -9.309  -20.611  -18.957  -17.075  -12.949    8.000
 2  -13.470   -9.536  -20.771  -18.737  -17.150  -13.061  -17.795     3.000
DC/DT= 1.774516     T =   3163.45
 2  -13.460   -9.536  -20.777  -18.7 6  -17.150  -13.062  -17.002     2.000
DC/DT= 1.764190     T =   3161.35
 3  -13.467   -9.197  -20.631  -18.976  -17.090  -12.966  -17.115     4.000
 3  -13.466   -9.100  -20.636  -18.986  -17.091  -12.969  -17.121     2.000
 3  -13.466   -9.100  -20.636  -18.986  -17.091  -12.965  -17.126     2.000
 3  -13.466   -9.100  -20.636  -18.986  -17.091  -12.960  -17.126     1.000
 4  -16.380   -9.261  -21.960  -20.650  -17.645  -12.995  -20.431     4.000
 4  -16.365   -9.026  -21.316  -20.476  -17.660  -13.006  -20.309     3.000
 4  -16.366   -9.326  -21.016  -20.473  -17.669  -13.006  -20.309     1.000
 5  -16.426  -10.131  -22.911  -22.182  -17.421  -12.696  -22.796     4.000
 5  -16.776  -10.313  -22.756  -21.610  -17.765  -13.110  -21.977     3.000
 5  -16.653  -10.218  -22.702  -21.637  -17.735  -13.011  -21.036     3.000
 6  -16.653  -10.218  -22.702  -21.637  -17.735  -13.011  -21.900     2.000
 6  -16.687  -10.657  -22.931  -21.630  -17.518  -13.679  -21.996     3.000
 6  -16.820  -10.105  -21.060  -22.020  -17.856  -13.149  -22.466     3.000
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6	-14.838	-10.605	-23.802	-22.108	-17.873	-13.152	-22.796	2.000
7	-15.014	-10.585	-23.875	-23.960	-18.242	-12.775	-25.306	4.000
7	-15.002	-10.572	-23.816	-23.635	-18.244	-12.887	-25.107	2.000
8	-15.200	-10.703	-24.866	-25.635	-19.043	-12.197	-28.570	4.000
8	-15.210	-10.703	-24.020	-25.567	-19.118	-12.161	-28.758	2.000
9	-15.359	-10.936	-25.693	-27.868	-20.002	-11.668	-31.392	4.000
9	-15.348	-10.922	-25.677	-26.936	-19.917	-11.696	-31.165	3.000

THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION

RESTRICTED EQUILIBRIUM OPTION

PC = 561.0 PSIA

	CHEMICAL FORMULA	WT FRACTION (SEE NOTE)	ENTHALPY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	N 1.00000 H 4.00000 CL 1.00000 O 4.00000	.70000	-70690.000	S	298.15	-0.0000
FUEL	AL 1.00000	.16000	0.000	S	298.15	-0.0000
FUEL	C 7.31900 H 10.50900 O .09000	.14000	11700.000	S	298.15	-0.0000

O/F=0. PERCENT FUEL=0. EQUIVALENCE RATIO= .1805E+01 STOIC MIXTURE RATIO=0. DENSITY=0.

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7466	1.0305	7.9090	20.773	34.582	68.789	170.74	287.03
P, PSIA	561.0	321.2	539.7	70.92	27.01	16.22	8.155	3.286	1.960
T, DEG R	6051	5656	6023	4445	4147	4006	3609	3129	2891
H, BTU/LB	-729.6	-965.5	-745.7	-1522.3	-1820.5	-1960.4	-2156.6	-2369.9	-2490.1
S, BTU/(LB)(R)	2.3302	2.3302	2.3302	2.3302	2.3302	2.3302	2.3302	2.3302	2.3302
DEN (LBM/FT3)	.235	.145	.228	.397E-01	.169E-01	.106E-01	.593E-02	.276E-02	.178E-02
M, MOL WT	27.263	27.488	27.280	27.936	28.053	28.075	28.150	28.268	28.296
(DLV/DLP)T	-1.01691	-1.01165	-1.01529	-1.00433	-1.00266	-1.00236	-1.00163	-1.00127	-1.00106
(DLV/DLT)P	1.3031	1.2855	1.2844	1.0866	0.0000	1.0608	1.0367	1.0293	1.0266
CP, BTU/(LB)(R)	.8737	.7073	.8617	.5587	0.0000	.5006	.4719	.4590	.4566
GAMMA (S)	1.1627	1.1586	1.1570	1.1700	.9073	1.1813	1.1884	1.1920	1.1930
SON VEL,FT/SEC	3550.0	3442.3	3543.6	3111.6	2713.9	2896.8	2751.6	2562.6	2457.6
MACH NUMBER	0.0000	1.0000	.2897	2.0286	2.7236	2.7220	3.0496	3.5367	3.9093
VEL,FT/S	0.	3442.	926.	6302.	7392.	7886.	8447.	9062.	9362.
AE/AT		1.0000	2.3000	2.0000	4.0000	6.0002	10.000	20.000	30.000
CSTAR, FT/SEC		5180	5180	5180	5180	5180	5180	5180	5180
CF		.663	.178	1.215	1.425	1.519	1.625	1.737	1.806
IVAC,LBF-SEC/LB		190.3	397.0	234.7	260.8	272.9	286.0	300.6	307.0
I, LBF-SEC/LBM		107.0	28.7	195.9	229.7	246.9	262.5	281.7	291.0
MOL WT(MIX)	25.378	25.572	24.302	25.950	26.040	26.080	26.151	26.228	26.270

MOLE FRACTIONS

AL	.000130	.000086	.000135	.000012	.000001	.000002	.000000	.000000	0.000000
ALCL	.005236	.005088	.008207	.001784	.002033	.002762	.001464	.000520	.000108
ALCL2	.003900	.006732	.003376	.004460	.006359	.007111	.007884	.007035	.005291
ALCL3	.000166	.002182	.000166	.000463	.000782	.000871	.001731	.004506	.004001
ALH	.000029	.000011	.000019	.000001	.000004	.000000	.000000	0.000002	0.000000
ALO	.000190	.000063	.000195	.000008	.000007	.000001	.000000	0.000000	0.000000
ALOCL	.001606	.001569	.001806	.001501	.001371	.001360	.000807	.000624	.000103
ALOH	.000637	.000307	.000626	.000290	.000156	.000136	.000071	.000018	.000006
ALO2	.000021	.000013	.000021	.000002	.000000	.000000	.000000	0.000000	0.000000
ALO2H	.000530	.000500	.000520	.000306	.000255	.000236	.000136	.000061	.000015
AL2O	.000027	.000023	.000027	.000000	.000005	.000006	.000001	.000000	.000000
AL2O3(S)	0.000000	0.000000	0.000000	0.000000	.032461	.071006	.071380	.071689	.071603
AL2O3(L)	.069171	.069700	.069218	.070751	.038600	0.000000	0.000000	0.000000	0.000000

CH2O	.000002	.000001	.000002	.000000	.000000	.000000	.000000	.000000	0.000000
CO	.264011	.268036	.264085	.264640	.264750	.268204	.266565	.262966	.260117
COCL	.000009	.000004	.000008	.000001	.000000	.000000	.000000	0.000000	0.000000
CO2	.012962	.013742	.013014	.016275	.018050	.018793	.021187	.025552	.028829
CL	.019451	.007958	.010272	.002457	.001294	.001045	.000386	.000075	.000029
CLO	.000005	.000002	.000004	.000000	.000000	0.000000	0.000000	0.000000	0.000000
CL2	.000016	.000010	.000015	.000002	.000001	.000000	.000000	.000000	0.000000
H	.035464	.026508	.034795	.008536	.006100	.003299	.001212	.000242	.000083
HCL	.125463	.128534	.125875	.133190	.133401	.133393	.131466	.127651	.126893
HCN	.000006	.000004	.000008	.000001	.000000	.000000	.000000	.000000	.000000
HCO	.000020	.000010	.000010	.000001	.000000	.000000	.000000	.000000	0.000000
HNO	.000001	.000000	.000001	.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H2	.287130	.291975	.287470	.303086	.305571	.309902	.316560	.321698	.326726
H2O	.117593	.120061	.117832	.126457	.126412	.123925	.122728	.119634	.116890
N	.000005	.000002	.000004	.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NH	.000000	.000000	.000000	.000000	.000000	.000000	0.000000	0.000000	0.000000
NH2	.000010	.000001	.000000	.000001	.000000	.000000	.000000	0.000000	0.000000
NH3	.000010	.000004	.000000	.000002	.000001	.000001	.000001	.000000	.000000
NO	.000620	.000242	.000417	.000030	.000008	.000005	.000001	.000000	0.000000
N2	.075366	.076064	.075417	.077310	.077629	.077600	.077906	.078133	.078254
O	.000461	.000294	.000460	.000015	.000002	.000001	.000000	0.000000	0.000000
OH	.006236	.004062	.006068	.000700	.000270	.000109	.000047	.000005	.000001
O2	.000075	.000030	.000072	.000002	.000000	.000000	.000000	0.000000	0.000000

AL(S)	0.	0.	0.	0.	0.	0.	0.	0.	0.
AL(L)	0.	0.	0.	0.	0.	0.	0.	0.	0.
ALCL3(S)	0.	0.	0.	0.	0.	0.	0.	0.	0.
ALCL3(L)	0.	0.	0.	0.	0.	0.	0.	0.	0.
ALN(S)	0.	0.	0.	0.	0.	0.	0.	0.	0.
ALN	1.09E-08	0.	1.02E-08	0.	0.	0.	0.	0.	0.
AL2CL6	0.	0.	0.	0.	0.	0.	0.	0.	0.
AL2O2	3.69E-07	2.09E-07	3.66E-07	1.36E-07	7.13E-08	5.95E-08	1.02E-08	0.	0.
C(S)	0.	0.	0.	0.	0.	0.	0.	0.	0.
C	0.	0.	0.	0.	0.	0.	0.	0.	0.
CCL	0.	0.	0.	0.	0.	0.	0.	0.	0.
CCL2	0.	0.	0.	0.	0.	0.	0.	0.	0.
CCL3	0.	0.	0.	0.	0.	0.	0.	0.	0.
CCL4	0.	0.	0.	0.	0.	0.	0.	0.	0.
CH	0.	0.	0.	0.	0.	0.	0.	0.	0.
CH2	0.	0.	0.	0.	0.	0.	0.	0.	0.
CH3	4.68E-08	2.05E-08	4.42E-08	0.	0.	0.	0.	0.	0.
CH4	1.75E-08	1.01E-08	1.68E-08	0.	0.	0.	0.	0.	0.
CN	1.30E-07	4.78E-08	1.25E-07	0.	0.	0.	0.	0	0.
CNN	0.	0.	0.	0.	0.	0.	0.	0.	0.
CN2	0.	0.	0.	0.	0.	0.	0.	0.	0.
COCL2	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2CL2	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2H	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2H2	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2H4	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2N	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2N2	0.	0.	0.	0.	0.	0.	0.	0.	0.
C2O	0.	0.	0.	0.	0.	0.	0.	0.	0.
C3	0.	0.	0.	0.	0.	0.	0.	0.	0.
C3O2	0.	0.	0.	0.	0.	0.	0.	0.	0.
C4	0.	0.	0.	0.	0.	0.	0.	0.	0.
C5	0.	0.	0.	0.	0.	0.	0.	0.	0.
CLCN	2.91E-08	1.10E-08	2.77E-08	0.	0.	0.	0.	0.	0.
CLO2	0.	0.	0.	0.	0.	0.	0.	0.	0.
CL2O	0.	0.	0.	0.	0.	0.	0.	0.	0.
HALO	6.95E-07	2.22E-07	6.14E-07	2.06E-08	0.	0.	0.	0.	0.
HNCO	6.55E-07	2.53E-07	6.17E-07	4.01E-08	1.78E-08	1.06E-08	0.	0.	0.
HO2	3.25E-07	1.10E-07	3.06E-07	0.	0.	0.	0.	0.	0.
H2O(S)	0.	0.	0.	0.	0.	0.	0.	0.	0.

H2O(L)	0.	0.	0.	0.	0.	0.	0.	0.	0.
H2O2	2.07E-07	8.27E-08	1.91E-07	0.	0.	0.	0.	0.	0.
NCO	3.65E-08	1.29E-08	3.23E-08	0.	0.	0.	0.	0.	0.
NOCL	4.12E-08	1.51E-08	3.88E-08	0.	0.	0.	0.	0.	0.
NO2	2.08E-08	0.	1.94E-08	0.	0.	0.	0.	0.	0.
NO2CL	0.	0.	0.	0.	0.	0.	0.	0.	0.
N2H4	0.	0.	0.	0.	0.	0.	0.	0.	0.
N2O	4.39E-08	1.87E-08	4.15E-08	0.	0.	0.	0.	0.	0.
N2O4	0.	0.	0.	0.	0.	0.	0.	0.	0.
N2	0.	0.	0.	0.	0.	0.	0.	0.	0.
O3	0.	0.	0.	0.	0.	0.	0.	0.	0.

MASS FRACTION OF TOTAL CONDENSIBLES

CONDENSIBLES	.277911	.277911	.277911	.277911	.277911	.277911	.277911	.277911	.277911

MOLECULAR WEIGHT OF TOTAL CONDENSIBLES IN THE CHAMBER= 101.9612

GAS MOLECULAR WT IN THE CHAMBER= 19.8867

EROSION PARAMETER BETA= .13008

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

EQUILIBRIUM CONTRACTION CONDITIONS ZONE 1

TEMPERATURE	(DEGR)	.60229423E+04
PRESSURE	(PSIA)	.53965670E+03
VELOCITY	(FT/S)	.92434372E+03

SPECIES MOLE FRACTIONS

1	AL(S)	0.
2	AL(L)	0.
3	AL	.13470356E-03
4	ALCL	.52031959E-02
5	ALCL2	.30362013E-02
6	ALCL3(S)	0.
7	ALCL3(L)	0.
8	ALCL3	.14613752E-03
9	ALH	.10344481E-04
10	ALN(S)	0.
11	ALN	.10190239E-07
12	ALO	.10672592E-03
13	ALOCL	.15040320E-02
14	ALOH	.62439951E-03
15	ALO2	.20440208E-04
16	ALO2H	.52005005E-03
17	AL2CL6	0.
18	AL2O	.24917053E-06
19	AL2O2	.36612701E-06
20	AL2O3(S)	0.
21	AL2O3(L)	.40200479E-01
22	C(S)	0.
23	C	0.
24	CCL	0.
25	CCL2	0.
26	CCL3	0.
27	CCL4	0.
28	CH	0.
29	CH2	0.
30	CH2O	.15440738E-05
31	CH3	.44230747E-07
32	CH4	.14778149E-07
33	CN	.12500104E-04
34	CNN	0.
35	CN2	0.
36	CO	.24400513E+00
37	COCL	.74347524E-05
38	COCL2	0.
39	CO2	.13014227E-01
40	C2	0.
41	C2CL2	0.
42	C2H	0.
43	C2H2	0.
44	C2H4	0.
45	C2N	0.
46	C2N2	0.
47	C2O	0.
48	C3	0.
49	C3O2	0.
50	C4	0.
51	C5	0.
52	CL	.10272360E-01

53	CLCN	.23717506E-07
54	CLO	.43674049E-05
55	CLO2	0.
56	CL2	.15469950E-06
57	CL2O	0.
58	H	.34795173E-01
59	HALO	.41502850E-06
60	HCL	.12587567E+00
61	HCN	.61550050E-05
62	HCO	.10027610E-06
63	HNCO	.43956075E-06
64	HNO	.64209606E-06
65	HNO2	.30464087E-06
66	H2	.20747014E+00
67	H2O(S)	0.
68	H2O(L)	0.
69	H2O	.11783195E+00
70	H2O2	.10071016E-06
71	N	.66780922E-05
72	NCO	.32301712E-07
73	NH	.83796378E-05
74	NH2	.91472977E-06
75	NH3	.87928637E-05
76	NO	.41230897E-03
77	NOCL	.30561302E-07
78	NO2	.19610615E-07
79	NO2CL	0.
80	N2	.75616066E-01
81	N2H4	0.
82	N2O	.61466066E-07
83	N2O4	0.
84	N3	0.
85	O	.44028210E-03
86	OH	.60677971E-02
87	O2	.73063761E-04
88	O3	0.

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$$$$$$$$$$ CURRENT EXECUTION TIME THIS CASE =        .165  (MIN) $$$$$$$$$$

REACTIONS
 CO + O  =     CO2   . A=6.05E18,  N=0.  .  H=2.6,                        BAULCH (1968)L)
 CL2     =   CL + CL . A=2.E13,    N=0.  .  B=66.450.                     SOLOMON(1971)
 HCL     =    H + CL . A=6.86E21,  N=2.  .  B=102.17,                     JACOBS (1966)
 HO2     =    H + O2 . A=2.40E15,  N=0.0 .  B=65.0 .               NO.36 BAULCH (1969)
 H2      =    H + H  . A=7.00E12,  N=-.50, B=92.60,                NO.3 BROKAW    (1970)
 H + OH  =      H2O  . A=3.00E19,  A=1.00, B= 0.00,                NO.5  PREHN    (1967)
 O2      =    O + O  . A=2.05E19,  N=1.00, B=118.7,                NO.1 JOHNSTON (1968)
 ALCL+ CL    = ALCL2        . A=3.0E16  .N= 0.5   .B= 0.0   .          31
 ALCL2+CL    = ALCL3        . A=3.0E16  .N= 0.5   .B= 0.0   .          32
 ALCL+ O     = ALOCL        . A=3.0E16  .N= 0.5   .B= 0.0   .          41
AL + H = ALH .         A=  3.0E16 . N=  0.5 . B=   0.0. ESTIMATE
H + ALO2 = ALO2H .     A=  3.0E16 . N=  0.5 . B=   0.0. ESTIMATE
OH + ALO = ALO2H .     A=  3.0E16 . N=  0.5 . B=   0.0. ESTIMATE
ALO + H = ALOH .       A=  3.0E16 . N=  0.5 . B=   0.0. ESTIMATE
END TAB REAC
 CO +CLO = CO2 + CL  . A=1.E11  .   N=-.5 .  B=3.6.                       ESTIMATE
 CO + O  =     CO2   . A=1.78E14.   N=0.  .  B=2.53.                      BAULCH (1968)L)
 CO + OH = CO2 + H   . A=5.6E11 .   N=0.  .  B=1.08.                      BAULCH (1968)L)
CO2 + H2 =  CO +H2O  . A=9.5E8  .   N=-.5 .  B=15..                       TUNDER (1967)
 CO2+ O  = CO  + O2  . A=1.9E13 .   N=0.  .  B=54.15.                     BAULCH (1968)L)
 CL  + HO2= CLO + OH . A=5.E11  .   N=-.5 .  B=3.5.                       ESTIMATE
 CL  + HO2= HCL + O2 . A=5.E11  .   N=-.5 .  B=2.6.                       ESTIMATE
 CL  + H2 = HCL + H  . A=1.2E13.    N=0.  .  B=6.2.                       WESTONBERG (68
 CL  + OH = HCL + O  . A=2.0E11.    N=-.67.  B=.1     .                   MAYER  (1967)
 CLO+ H  = HCL + O   . A=5.E11  .   N=-.5 .  B=3.56.                      ESTIMATE
 CLO+ O  =  CL + O2  . A=5.E11  .   N=-.5 .  B=3.56.                      ESTIMATE
CL2 + H  = HCL + CL  . A=3.0E14.    N=0.  .  B=3.0.                       CHERRY (1967)
CL2 + O  = CLO + CL  . A=5.E11  .   N=-.5 .  B=3.2.                       ESTIMATE
 HCL + OH = H2O + CL . A=1.0E11.    N=-.5 .  B=5.0  .                     CHERRY (1967)
 H2 + O  =  H + OH   . A=2.94E13.   N=0.00,  B= 9.00,              NO.19 BRABBS   (1970)
 H2 + OH =  H + H2O  . A=2.19E13.   N=0.00,  B= 5.15,              NO.20 BAULCH   (1968)
 OH + H2 =  H2 + O2  . A=1.E13  .   N=0.  .  B=76.0.                     BAULCH (1969)L6
 OH + OH =  O + H2O  . A=5.75E12.   N=0.00,  B= 0.78,              NO.21 BAULCH   (1968)
 O2 + H  =  OH + O   . A=1.44E14.   N=0.00,  B=16.60,              NO.18 BELLES   (1970)
 ALO  + CO     = AL    + CO2  .A=1.05E11.N=-.5      .B= 3.215 .           217
 ALO  + O      = AL    + O2   .A=5.0 E11.N=-.5      .B= 3.215 .           220
 AL2O + CL     = AL    + ALOCL.A=1.05E11.N=-.5      .B= 3.621 .           221
 AL   + OH     = ALO   + H    .A=5.0 E11.N=-.5      .B= 2.832 .           226
 ALO  + ALCL   = AL2O  + CL   .A=1.05E11.N=-.5      .B= 3.269 .           229
 ALCL2+ H      = ALCL  + HCL  .A=1.05E11.N=-0.5     .B=2.566  .           232
 AL    + CL2   = ALCL  + CL   .A=5.0 E11.N=-0.5     .B=1.6    .           235
 AL    + HCL   = ALCL  + H    .A=5.0 E11.N=-0.5     .B=2.853  .           236
 ALO   + CL    = ALCL  + O    .A=5.0 E11.N=-0.5     .B=2.853  .           237
 ALO   + ALCL2 = ALCL  + ALOCL.A=1.05E11.N=-0.5     .B=2.566  .           240
 ALCL  + CL2   = ALCL2 + CL   .A=1.05E11.N=-0.5     .B=1.6    .           242
 ALCL  + CO2   = ALOCL + CO   .A=1.05E11.N=-0.5     .B=3.520  .           243
 ALCL2+ OH     = ALOCL + HCL  .A=1.17E11.N=-0.5     .B=27.683 .           244
 ALO   + CL2   = ALOCL + CL   .A=1.05E11.N=-0.5     .B=1.6    .           245
 ALCL2+ O      = ALOCL + CL   .A=1.05E11.N=-0.5     .B=2.566  .           246
 ALO   + HCL   = ALOCL + H    .A=1.05E11.N=-0.5     .B=2.853  .           247
 ALCL  + OH    = ALOCL + H    .A=1.05E11.N=-0.5     .B=2.853  .           248
 ALCL  + O2    = ALOCL + O    .A=1.05E11.N=-0.5     .B=3.298  .           249
 ALCL2+ ALCL2  = ALCL  + ALCL3.A=1.05E11.N=-0.5     .B=2.566  .           306
 ALCL2+ CL2    = ALCL3 + CL   .A=1.05E11.N=-0.5     .B=1.6    .           311
 ALCL3+ H      = ALCL2 + HCL  .A=1.05E11.N=-0.5     .B=2.591  .           318
ALO + OH = ALO2 + H .      A=  1.0E11 . N= -0.5 . B=  5.6265. ESTIMATE
ALO + CLO = ALO2 + CL .    A=  1.0E11 . N= -0.5 . B=  3.5365. ESTIMATE
ALO + O2 = ALO2 + O .      A=  1.0E11 . N= -0.5 . B=  4.852 . ESTIMATE
ALO + HO2 = ALO2 + OH .    A=  1.0E11 . N= -0.5 . B=  3.6025. ESTIMATE
[illegible]                A=  1.0E11 . N= -0.5 . B=  5.531 . ESTIMATE
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ALO2 + H2 = H + ALO2H ,      A= 1.0E11 , N= -0.5 , B= 6.731 , ESTIMATE
ALO2 + OH = O + ALO2H ,      A= 1.0E11 , N= -0.5 , B= 5.6265, ESTIMATE
ALO2 + HCL = CL + ALO2H ,    A= 1.0E11 , N= -0.5 , B= 6.6705, ESTIMATE
ALO2H + H2 = ... + ALO2H ,   A= 1.0E11 , N= -0.5 , B= 6.556 , ESTIMATE
ALO2H + OH = ... ,           A= 1.0E11 , N= -0.5 , B= 5.6265, ESTIMATE
ALO2H + ... ,                A= 1.0E11 , N= -0.5 , B= 3.6365, ESTIMATE
AL + ... ,                   A= 1.0E11 , N= -0.5 , B= 7.0015, ESTIMATE
ALO + H2 = ... + H ,         A= 1.0E11 , N= -0.5 , B= 6.731 , ESTIMATE
ALO + HCL = ALOH + CL ,      A= 1.0E11 , N= -0.5 , B= 6.6705, ESTIMATE
AL + OH = ... + O ,          A= 1.0E11 , N= -0.5 , B= 5.6265, ESTIMATE
ALH + ... = AL + H2 ,        A= 6.0E11 , N= -0.5 , B= 3.74  , ESTIMATE
ALH + OH = AL + H2O ,        A= 1.0E11 , N= -0.5 , B= 3.74,   ESTIMATE
ALH + O = AL + OH ,          A= 6.0E11 , N= -0.5 , B= 3.74,   ESTIMATE
ALH + CL = AL + HCL ,        A= 6.0E11 , N= -0.5 , B= 3.74,   ESTIMATE
 AL + ALCL2=ALCL +ALCL, A=5.0E11,N=-0.5,B=4.1580,        ESTIMATE
LAST REAX
THIRD BODY REAX RATE RATIOS
ALL EQUAL 1.0
LAST CARD
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SPECIES TABLE

(OBTAINED FROM REACTIONS)

1	CO
2	O
3	CO2
4	CL2
5	CL
6	HCL
7	H
8	HO2
9	O2
10	H2
11	OH
12	H2O
13	ALCL
14	ALCL2
15	ALCL3
16	ALOCL
17	AL
18	ALH
19	ALO2
20	[illegible]
21	ALO
22	ALOH
23	CLO
24	HO
25	N2
26	AL2O

REACTION TABLE

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THIRD BODY REACTION   1   A=  .5150000E+16   B=  .2500000E+01   N= 0.
                  REACTANTS   CL              + O
                  PRODUCTS    CLO

THIRD BODY REACTION   2   A=  .2000000E+16   B=  .6450000E+02   N= 0.
                  REACTANTS   CL2
                  PRODUCTS    CL              + CL

THIRD BODY REACTION   3   A=  .8000000E+22   B=  .1021700E+03   N=  .2000000E+01
                  REACTANTS   HCL
                  PRODUCTS    H               + CL

THIRD BODY REACTION   4   A=  .2600000E+16   B=  .6590000E+02   N= 0.
                  REACTANTS   HO2
                  PRODUCTS    H               + O2

THIRD BODY REACTION   5   A=  .7000000E+13   B=  .9260000E+02   N= -.5000000E+00
                  REACTANTS   H2
                  PRODUCTS    H               + H

THIRD BODY REACTION   6   A=  .1000000E+20   B= 0.              N=  .1000000E+01
                  REACTANTS   H               + OH
                  PRODUCTS    H2O

THIRD BODY REACTION   7   A=  .2000000E+20   B=  .1187000E+03   N=  .1000000E+01
                  REACTANTS   O2
                  PRODUCTS    O               + O

THIRD BODY REACTION   8   A=  .1000000E+17   B= 0.              N=  .5000000E+00
                  REACTANTS   ALCL            + CL
                  PRODUCTS    ALCL2

THIRD BODY REACTION   9   A=  .1000000E+17   B= 0.              N=  .5000000E+00
                  REACTANTS   ALCL2           + CL
                  PRODUCTS    ALCL3

THIRD BODY REACTION  10   A=  .1000000E+17   B= 0.              N=  .5000000E+00
                  REACTANTS   ALCL            + O
                  PRODUCTS    ALOCL

THIRD BODY REACTION  11   A=  .1000000E+17   B= 0.              N=  .5000000E+00
                  REACTANTS   AL              + H
                  PRODUCTS    ALH

THIRD BODY REACTION  12   A=  .1000000E+17   B= 0.              N=  .5000000E+00
                  REACTANTS   H               + ALO2
                  PRODUCTS    ALO2H

THIRD BODY REACTION  13   A=  .1000000E+17   B= 0.              N=  .5000000E+00
                  REACTANTS   OH              + ALO
                  PRODUCTS    ALO2H

THIRD BODY REACTION  14   A=  .1000000E+17   B= 0.              N=  .5000000E+00
                  REACTANTS   ALO             + H
                  PRODUCTS    ALOH

           REACTION  15   A=  .1000000E+13   B=  .3000000E+01   N= -.5000000E+00
                  REACTANTS   CO              + CLO
                  PRODUCTS    CO2             + CL

           REACTION  16   A=  .1700000E+11   B=  .2510000E+01   N= 0.
                  REACTANTS   CO              + O
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         PRODUCTS    CO2

REACTION  17   A=   .4400000E+12    B=   .1000000E+01    N= 0.
         REACTANTS   CO             + OH
         PRODUCTS    CO2            + H

REACTION  18   A=   .9400000E+00    B=   .1500000E+02    N= -.5030000E+00
         REACTANTS   CO2            + H2
         PRODUCTS    CO             + H2O

REACTION  19   A=   .1900000E+16    B=   .5415000E+02    N= 0.
         REACTANTS   CO2            + O
         PRODUCTS    CO             + O2

REACTION  20   A=   .5800000E+12    B=   .3500000E+01    N= -.5000000E+03
         REACTANTS   CL             + HO2
         PRODUCTS    CLO            + OH

REACTION  21   A=   .5800000E+12    B=   .2600000E+01    N= -.5000000E+00
         REACTANTS   CL             + HO2
         PRODUCTS    HCL            + O2

REACTION  22   A=   .1200000E+14    B=   .4300000E+01    N= 0.
         REACTANTS   CL             + H2
         PRODUCTS    HCL            + H

REACTION  23   A=   .2000000E+12    B=   .1000000E+00    N= -.4750000E+00
         REACTANTS   CL             + OH
         PRODUCTS    HCL            + O

REACTION  24   A=   .5800000E+12    B=   .3540000E+01    N= -.5000000E+00
         REACTANTS   CLO            + H
         PRODUCTS    HCL            + O

REACTION  25   A=   .5800000E+12    B=   .3540000E+01    N= -.5000000E+01
         REACTANTS   CLO            + O
         PRODUCTS    CL             + O2

REACTION  26   A=   .3800000E+14    B=   .3000000E+01    N= 0.
         REACTANTS   CL2            + H
         PRODUCTS    HCL            + CL

REACTION  27   A=   .4300000E+12    B=   .3700000E+01    N= -.[illegible]
         REACTANTS   CL2            + O
         PRODUCTS    CLO            + CL

REACTION  28   A=   .1300000E+12    B=   .6300000E+01    N= -.[illegible]
         REACTANTS   HCL            + OH
         PRODUCTS    H2O            + CL

REACTION  29   A=   .2000000E+14    B=   .4800000E+01    N= 0.
         REACTANTS   H2             + O
         PRODUCTS    H              + OH

REACTION  30   A=   .2100000E+14    B=   .5150000E+01    N= 0.
         REACTANTS   H2             + OH
         PRODUCTS    H              + H2O

REACTION  31   A=   .1000000E+14    B=   .7400000E+02    N= 0.
         REACTANTS   HO             + HO
         PRODUCTS    H2             + O2

REACTION  32   A=   .4700000E+13    B=   .7800000E+00    N= 0.
         REACTANTS   OH             + OH
         PRODUCTS    O              + H2O
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REACTION 33   A= .1440000E+15   B= .1660000E+02   N= 0.
       REACTANTS  O2        + H
       PRODUCTS   OH        + O

REACTION 34   A= .1050000E+12   B= .3215000E+01   N= -.5000000E+00
       REACTANTS  ALO       + CO
       PRODUCTS   AL        + CO2

REACTION 35   A= .5300000E+12   B= .3215000E+01   N= -.5000000E+00
       REACTANTS  ALO       + O
       PRODUCTS   AL        + O2

REACTION 36   A= .1050000E+12   B= .3621000E+01   N= -.5000000E+00
       REACTANTS  AL2O      + CL
       PRODUCTS   AL        + ALOCL

REACTION 37   A= .5300000E+12   B= .2832000E+01   N= -.5000000E+00
       REACTANTS  AL        + OH
       PRODUCTS   ALO       + H

REACTION 38   A= .1050000E+12   B= .3269000E+01   N= -.5000000E+00
       REACTANTS  ALO       + ALCL
       PRODUCTS   AL2O      + CL

REACTION 39   A= .1050000E+12   B= .2566000E+01   N= -.5000000E+00
       REACTANTS  ALCL2     + H
       PRODUCTS   ALCL      + HCL

REACTION 40   A= .5300000E+12   B= .1600000E+01   N= -.5000000E+00
       REACTANTS  AL        + CL2
       PRODUCTS   ALCL      + CL

REACTION 41   A= .5300000E+12   B= .2853000E+01   N= -.5000000E+00
       REACTANTS  AL        + HCL
       PRODUCTS   ALCL      + H

REACTION 42   A= .5300000E+12   B= .2853000E+01   N= -.5000000E+00
       REACTANTS  ALO       + CL
       PRODUCTS   ALCL      + O

REACTION 43   A= .1050000E+12   B= .2566000E+01   N= -.5000000E+00
       REACTANTS  ALO       + ALCL2
       PRODUCTS   ALCL      + ALOCL

REACTION 44   A= .1050000E+12   B= .1600000E+01   N= -.5000000E+00
       REACTANTS  ALCL      + CL2
       PRODUCTS   ALCL2     + CL

REACTION 45   A= .1050000E+12   B= .3520000E+01   N= -.5000000E+00
       REACTANTS  ALCL      + CO2
       PRODUCTS   ALOCL     + CO

REACTION 46   A= .1750000E+11   B= .2748300E+02   N= -.5000000E+00
       REACTANTS  ALCL2     + OH
       PRODUCTS   ALOCL     + HCL

REACTION 47   A= .1050000E+12   B= .1600000E+01   N= -.5000000E+00
       REACTANTS  ALO       + CL2
       PRODUCTS   ALOCL     + CL

REACTION 48   A= .1050000E+12   B= .2566000E+01   N= -.5000000E+00
       REACTANTS  ALCL2     + O
       PRODUCTS   ALOCL     + CL

REACTION 49   A= .1050000E+12   B= .2853000E+01   N= -.5000000E+00
       REACTANTS  ALO       + HCL
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         PRODUCTS   ALOCL          + H

REACTION  50   A=   .1050000E+12   B=  .2853000E+01   N= -.5000000E+00
         REACTANTS  ALCL           + OH
         PRODUCTS   ALOCL          + H

REACTION  51   A=   .1050000E+12   B=  .3296000E+01   N= -.5000000E+00
         REACTANTS  ALCL           + O2
         PRODUCTS   ALOCL          + O

REACTION  52   A=   .1050000E+12   B=  .2566000E+01   N= -.5000000E+00
         REACTANTS  ALCL2          + ALCL2
         PRODUCTS   ALCL           + ALCL3

REACTION  53   A=   .1050000E+12   B=  .1690000E+01   N= -.5000000E+00
         REACTANTS  ALCL2          + CL2
         PRODUCTS   ALCL3          + CL

REACTION  54   A=   .1050000E+12   B=  .2591000E+01   N= -.5000000E+00
         REACTANTS  ALCL3          + H
         PRODUCTS   ALCL2          + HCL

REACTION  55   A=   .1000000E+12   B=  .5626500E+01   N= -.5000000E+00
         REACTANTS  ALO            + OH
         PRODUCTS   ALO2           + H

REACTION  56   A=   .1000000E+12   B=  .3534500E+01   N= -.5000000E+00
         REACTANTS  ALO            + CLO
         PRODUCTS   ALO2           + CL

REACTION  57   A=   .1000000E+12   B=  .6552000E+01   N= -.5000000E+00
         REACTANTS  ALO            + O2
         PRODUCTS   ALO2           + O

REACTION  58   A=   .1000000E+12   B=  .3602500E+01   N= -.5000000E+00
         REACTANTS  ALO            + HO2
         PRODUCTS   ALO2           + OH

REACTION  59   A=   .1000000E+12   B=  .5731000E+01   N= -.5000000E+00
         REACTANTS  ALO2           + H2
         PRODUCTS   H              + ALO2H

REACTION  60   A=   .1000000E+12   B=  .56[illegible]E+01   N= -.5000000E+00
         REACTANTS  ALO2           + OH
         PRODUCTS   O              + ALO2H

REACTION  61   A=   .1000000E+12   B=  .5[illegible]E+01   N= -.5000000E+00
         REACTANTS  ALO2           + HCL
         PRODUCTS   CL             + ALO2H

REACTION  62   A=   .1000000E+12   B=  .6556000E+01   N= -.5000000E+00
         REACTANTS  ALOH           + O2
         PRODUCTS   O              + ALO2H

REACTION  63   A=   .1000000E+12   B=  .[illegible]E+01   N= -.5000000E+00
         REACTANTS  ALOH           + OH
         PRODUCTS   H              + ALO2H

REACTION  64   A=   .1000000E+12   B=  .35[illegible]E+01   N= -.5000000E+00
         REACTANTS  ALOH           + CLO
         PRODUCTS   CL             + ALO2H

REACTION  65   A=   .6000000E+12   B=  .7001500E+01   N= -.5000000E+00
         REACTANTS  AL             + H2O
         PRODUCTS   ALOH           + H
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REACTION  66   A=  .1000000E+12   B=  .5731000E+01   N= -.5000000E+00
        REACTANTS  ALO          + H2
        PRODUCTS   ALOH         + H

REACTION  67   A=  .1000000E+12   B=  .5670500E+01   N= -.5000000E+00
        REACTANTS  ALO          + HCL
        PRODUCTS   ALCL         + CL

REACTION  68   A=  .1000000E+12   B=  .5626500E+01   N= -.5000000E+00
        REACTANTS  ALO          + OH
        PRODUCTS   ALOH         + O

REACTION  69   A=  .5000000E+12   B=  .3740000E+01   N= -.5000000E+00
        REACTANTS  ALH          + H
        PRODUCTS   AL           + H2

REACTION  70   A=  .1000000E+12   B=  .3740000E+01   N= -.5000000E+00
        REACTANTS  ALH          + OH
        PRODUCTS   AL           + H2O

REACTION  71   A=  .5000000E+12   B=  .3740000E+01   N= -.5000000E+00
        REACTANTS  ALH          + O
        PRODUCTS   AL           + OH

REACTION  72   A=  .5000000E+12   B=  .3740000E+01   N= -.5000000E+00
        REACTANTS  ALH          + CL
        PRODUCTS   AL           + HCL

REACTION  73   A=  .5000000E+12   B=  .4158000E+01   N= -.5000000E+00
        REACTANTS  AL           + ALCL2
        PRODUCTS   ALCL         + ALCL
```

SELECTED SPECIES FOR KINETIC EXPANSION

3	AL	.13470354E-03	
4	ALCL	.52831959E-02	
5	ALCL2	.39342813E-02	
8	ALCL3	.14613752E-03	
9	ALH	.19364481E-04	
12	ALO	.10473528E-03	
13	ALOCL	.15840320E-02	
14	ALOH	.42439951E-03	
15	ALO2	.20640208E-04	
16	ALO2H	.52805905E-03	
18	AL2O	.26917653E-04	
20	AL2O3(S)	0.	INERT SPECIES
21	AL2O3(L)	.40209679E-01	INERT SPECIES
35	CO	.24490533E+00	
39	CO2	.13016227E-01	
52	CL	.10272350E-01	
54	CLO	.43476945E-05	
56	CL2	.15458950E-04	
58	H	.34795173E-01	
60	HCL	.12587547E+00	
65	HCO	[illegible]	
66	H2	.24747315E+00	
69	H2O	.11781155E+00	
78	NO	[illegible]	
86	N2	.75416854E-01	
88	O	.46028230E-03	
94	OH	[illegible]	
97	O2	[illegible]	

DISSOCIATION RECOMBINATION REACTION RATE RATIOS

ALL REACTION RATE RATIOS INPUT AS 1.0

CONTOURED NOZZLE OPTION SELECTED, WALL TABLE IS

I	RWZS(I)	RWRS(I)	WALL SLOPE
1	.78146E+00	.11590E+01	.42467E+00
2	.12815E+01	.13712E+01	.42464E+00
3	.15000E+01	.16660E+01	.42399E+00
4	.25000E+01	.18865E+01	.42000E+00
5	.35000E+01	.23129E+01	.40862E+00
6	.45000E+01	.27376E+01	.40129E+00
7	.55210E+01	.32695E+01	.36263E+00
8	.66650E+01	.36833E+01	.33194E+00
9	.88075E+01	.43051E+01	.32891E+00
10	.10626E+02	.49426E+01	.27894E+00
11	.12795E+02	.55532E+01	.24033E+00

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ALPHA= .38691 ALPHA BAR= .27703

$$$$$$$$$$ CURRENT EXECUTION TIME THIS CASE = .213 (MIN) $$$$$$$$$$

INITIAL CONDITIONS KINETIC EXPANSION

FLOW PROPERTIES		NOZZLE GEOMETRY	
MACH NUMBER	.25499083E+00	THROAT RADIUS (FT)	.17041667E+00
VELOCITY (FT/SEC)	.92430377E+03	THROAT WALL RADIUS DNSTREAM	.20000000E+01
PRESSURE (PSIA)	.51065670E+03	CONE ANGLE (DEG)	.23000000E+02
DENSITY (LB/FT3)	.22777671E+00	EXPANSION RATIO	0.
TEMPERATURE (DEG-R)	.60725629E+04	CONTRACTION RATIO	.23000000E+01
ENTHALPY (BTU/LB)	-.76611086E+03	INLET ANGLE (DEG)	.34000000E+02
GAS MOLECULAR WEIGHT	.19699013E+02	INLET WALL RADIUS	0.
HEAT CAPACITY (BTU/LB-DEG-R	.44230530E+00	THROAT WALL RADIUS UPSTREAM	.20000000E+01
GAMMA	.11971339E+01		
MOLECULAR WEIGHT(MIX)	.25391819E+02		

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.14314600E-03	.13471272E-03	2	ALCL	.12901460E-01	.52035561E-02
3	ALCL2	.15148010E-01	.39365495E-02	4	ALCL3	.74736710E-03	.14616740E-03
5	ALH	.21366982E-06	.19365801E-06	6	ALO	.17729826E-03	.10476242E-03
7	ALOCL	.46441005E-02	.15061345E-02	8	ALOH	.73520149E-03	.42462044E-03
9	ALO2	.47065092E-06	.20660615E-06	10	ALO2H	.12476270E-02	.52009505E-03
11	AL2O	.74171633E-06	.24910484E-06	12	AL2O3(S)	0.	0.
13	AL2O3(L)	.27799147E+00	.69214397E-01	14	CO	.27230805E+00	.24692216E+00
15	CO2	.22541706E-01	.13017114E-01	16	CL	.14363620E-01	.10273051E-01
17	CLO	.80510307E-06	.41679923E-06	18	CL2	.43171679E-06	.15460004E-06
19	H	.13013663E-02	.36797545E-01	20	HCL	.18879122E+00	.12580405E+00
21	HO2	.19579663E-06	.30660123E-06	22	H2	.22024765E-01	.28740975E+00
23	H2O	.83606690E-01	.11781958E+00	24	NO	.68726707E-03	.61233660E-03
25	N2	.83240079E-01	.75421997E-01	26	O	.27744115E-03	.44031232E-03
27	OH	.40444722E-02	.60443107E-02	28	O2	.90820530E-06	.72060253E-06

THROAT CONDITIONS   KINETIC EXPANSION

FLOW PROPERTIES

MACH NUMBER	.98480825E+00
PRESSURE (PSIA)	.37988038E+03
VELOCITY (FT/SEC)	.36420182E+04
DENSITY (LB/FT3)	.14559537E+00
TEMPERATURE (DEG-R)	.56512881E+04
ENTHALPY (BTU/LB)	-.14894129E+03
GAS MOLECULAR WEIGHT	.19846767E+02
HEAT CAPACITY(BTU/LB-DEG)	.63086351E+00
GAMMA	.11967253E+01
MOLECULAR WEIGHT(MIX)	.25868900E+02

PERFORMANCE PARAMETERS

VACUUM THRUST COEFFICIENT	.12353769E+01
VACUUM SPECIFIC IMPULSE (SEC)	.19922634E+03
CHARACTERISTIC VELOCITY (FT/SEC)	.51085820E+04

INTEGRATION PARAMETERS

STEP SIZE	.50000000E-02
AXIAL POSITION	0.
PERCENT ENTHALPY CHANGE	-.19102053E-01
PERCENT MASS FRACTION CHANGE	.30079850E-10

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.89292261E-06	.86617724E-06	2	ALCL	.17391304E-01	.50746499E-02
3	ALCL2	.16558580E-01	.43271639E-02	4	ALCL3	.96526620E-03	.19125736E-03
5	ALH	.12165853E-16	.11096776E-06	6	ALO	.10697628E-03	.63781219E-04
7	ALOCL	.67828300E-12	.15591749E-02	8	ALOH	.65812519E-03	.39756229E-03
9	ALO2	.30828269E-06	.13816308E-06	10	ALO2H	.11766964E-02	.50111667E-03
11	AL2O	.61758886E-06	.22570805E-06	12	AL2O3(S)	0.	0.
13	AL2O3(L)	.27793147E+00	.69697386E-01	14	CO	.27170645E+00	.24802306E+00
15	CO2	.23632617E-01	.13730130E-01	16	CL	.11069875E-01	.79685606E-02
17	CLO	.60261961E-05	.19098829E-05	18	CL2	.27885780E-06	.10095720E-06
19	H	.10647319E-02	.26552265E-01	20	HCL	.18327996E+00	.12052879E+00
21	HO2	.15666797E-06	.11091697E-06	22	H2	.23028678E-01	.29287968E+00
23	H2O	.86087188E-01	.12058703E+00	24	NO	.68716271E-03	.61512636E-03
25	N2	.83219828E-01	.75069360E-01	26	O	.14123830E-03	.22571608E-03
27	OH	.26885398E-02	.68578031E-02	28	O2	.66962069E-04	.37800568E-04

EXPANSION CONDITIONS KINETIC EXPANSION AREA RATIO 2.000

FLOW PROPERTIES		PERFORMANCE PARAMETERS	
MACH NUMBER	.20132140E+01	VACUUM THRUST COEFFICIENT	.16660702E+01
PRESSURE (PSIA)	.70202677E+02	VACUUM SPECIFIC IMPULSE (SEC)	.23642771E+03
VELOCITY (FT/SEC)	.63082420E+04		
DENSITY (LB/FT3)	.30704420E-01		
TEMPERATURE (DEG-R)	.45880286E+04	INTEGRATION PARAMETERS	
ENTHALPY (BTU/LB)	-.15244600E+04		
GAS MOLECULAR WEIGHT	.20102427E+02	STEP SIZE	.50000000E-02
HEAT CAPACITY(BTU/LB-DEG)	.43001207E+00	AXIAL POSITION	.13826925E+01
GAMMA	.11085445E+01	PERCENT ENTHALPY CHANGE	-.22273436E-01
CURRENT [illegible]	.50009371E+02	PERCENT MASS FRACTION CHANGE	.94502184E-10
MOLECULAR WEIGHT(MIX)	.28876351E+02		

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.20133231E-06	.19300584E-06	2	ALCL	.10774252E-01	.45060900E-02
3	ALCL2	.19153112E-01	.50630842E-02	4	ALCL3	.14614624E-02	.27196609E-03
5	ALH	.15760959E-05	.14576602E-05	6	ALO	.20405909E-06	.12205220E-04
7	ALOCL	.54060174E-02	.17828547E-02	8	ALOH	.45109873E-03	.20535770E-03
9	ALO2	.69632174E-05	.30110905E-05	10	ALO2H	.10072570E-02	.43640107E-03
11	AL2O	.34387060E-16	.12718759E-06	12	AL2O3(S)	0.	0.
13	AL2O3(L)	.27793147E+00	.70535186E-01	14	CO	.24931776E+00	.24870771E+00
15	CO2	.27385717E-01	.16103869E-01	16	CL	.50569324E-02	.36096020E-02
17	CLO	.24113386E-06	.12127062E-06	18	CL2	.51914693E-05	.10065320E-05
19	H	.45712534E-03	.11735206E-01	20	HCL	.18715446E+00	.13326936E+00
21	HO2	.10338360E-07	.81069747E-08	22	H2	.23567563E-01	.30193264E+00
23	H2O	.85703257E-01	.12322923E+00	24	NO	.48713760E-03	.42000260E-03
25	N2	.83209060E-01	.74081299E-01	26	O	.14561012E-06	.26709950E-06
27	OH	.60624092E-03	.10610580E-02	28	O2	.57141231E-06	.46708107E-06

●●

BEGIN SOLIDIFICATION OF AL2O3(L) T= 0.14679172E+03 MELTING TEMP= 0.14700000E+03

EXPANSION CONDITIONS KINETIC EXPANSION AREA RATIO 6.000

FLOW PROPERTIES	
MACH NUMBER	.24470559E+01
PRESSURE (PSIA)	.27196548E+02
VELOCITY (FT/SEC)	.73722481E+04
DENSITY (LB/FT3)	.14048064E-01
TEMPERATURE (DEG-R)	.61470084E+04
ENTHALPY (BTU/LB)	-.10158111E+04
GAS MOLECULAR WEIGHT	.28144044E+02
HEAT CAPACITY(BTU/LB-DEG)	.47471434E+00
GAMMA	.17015247E+01
CURRENT ROOVOA	.50030730E+02
MOLECULAR WEIGHT(MIX)	.25024160E+02

PERFORMANCE PARAMETERS	
VACUUM THRUST COEFFICIENT	.16147646E+01
VACUUM SPECIFIC IMPULSE (SEC)	.26040712E+03

INTEGRATION PARAMETERS	
STEP SIZE	.50000000E-02
AXIAL POSITION	.27501319E+01
PERCENT ENTHALPY CHANGE	-.62645360E-01
PERCENT MASS FRACTION CHANGE	.15774049E-09

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.11500075E-04	.11134029E-04	2	ALCL	.10858905E-01	.65092007E-02
3	ALCL2	.18474319E-01	.48038470E-02	4	ALCL3	.12957407E-02	.25193031E-03
5	ALH	.55474610E-06	.51570629E-06	6	ALO	.10861997E-04	.65510164E-05
7	ALOCL	.62390082E-02	.20419578E-02	8	ALOH	.30.86111E-03	.23096331E-03
9	ALO2	.30057271E-05	.17137760E-05	10	ALO2H	.07632136E-03	.47195355E-03
11	AL2O	.20307605E-04	.10510473E-04	12	AL2O3(S)	.19026701E+00	.46380000E-01
13	AL2O3(L)	.07644659E-01	.22290059E-01	14	CO	.24771788E+00	.24779579E+00
15	CO2	.29000635E-01	.17413608E-01	16	CL	.30567062E-02	.20020646E-02
17	CLO	.62078499E-07	.31603715E-07	18	CL2	.21009723E-05	.76020217E-06
19	H	.36002813E-03	.80979058E-02	20	HCL	.18010287E+00	.13044464E+00
21	HO2	.30714106E-08	.26129349E-08	22	H2	.23700163E-01	.30607503E+00
23	H2O	.80053814E-01	.12229837E+00	24	NO	.60713772E-03	.62090195E-03
25	N2	.83209060E-01	.77009247E-01	26	O	.73918677E-06	.11970000E-06
27	OH	.30500260E-03	.50702255E-03	28	O2	.25102073E-05	.20603071E-05

••

END OF SOLIDIFICATION OFAL2O3(L) AT Z= 3.07912460E+00 AREA RATIO= 6.56832072E+00

EXPANSION CONDITIONS KINETIC EXPANSION AREA RATIO 6.000

FLOW PROPERTIES

MACH NUMBER	.27723888E+01
PRESSURE (PSIA)	.15882673E+02
VELOCITY (FT/SEC)	.78033435E+04
DENSITY (LB/FT3)	.10876078E-01
TEMPERATURE (DEG-R)	.30081988E+04
ENTHALPY (BTU/LB)	-.10713968E+04
GAS MOLECULAR WEIGHT	.28158146E+02
HEAT CAPACITY(BTU/LB-DEG)	.41002715E+00
GAMMA	.12462181E+01
CURRENT MOLES	.50017547E+02
MOLECULAR WEIGHT(MIX)	.25033654E+02

PERFORMANCE PARAMETERS

VACUUM THRUST COEFFICIENT	.18003395E+01
VACUUM SPECIFIC IMPULSE (SEC)	.27263209E+03

INTEGRATION PARAMETERS

STEP SIZE	.50000000E-02
AXIAL POSITION	.30300079E+01
PERCENT ENTHALPY CHANGE	-.57070735E-01
PERCENT MASS FRACTION CHANGE	.20767868E-09

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.91571536E-05	.88016617E-05	2	ALCL	.11278915E-01	.46016065E-02
3	ALCL2	.17395702E-01	.44860153E-02	4	ALCL3	.11087611E-02	.21566365E-03
5	ALH	.20053367E-06	.26019179E-06	6	ALO	.78988377E-05	.47650365E-05
7	ALOCL	.67609607E-02	.22382219E-02	8	ALOH	.37066974E-03	.21851501E-03
9	ALO2	.25001518E-05	.13143208E-05	10	ALO2H	.96860287E-03	.41066905E-03
11	AL2O	.20551811E-06	.98671607E-07	12	AL2O3(S)	.27703167E+00	.70690046E-01
13	AL2O3(L)	0.	0.	14	CO	.26739022E+00	.24756403E+00
15	CO2	.30411073E-01	.17020136E-01	16	CL	.37522076E-02	.27466950E-02
17	CLO	.26200499E-07	.13285788E-07	18	CL2	.11411707E-05	.40276674E-06
19	H	.12587392E-03	.31062145E-02	20	HCL	.18978001E+00	.13690050E+00
21	HO2	.10082802E-08	.15637688E-08	22	H2	.23761052E-01	.30560966E+00
23	H2O	.86767325E-01	.12108977E+00	24	NO	.48713772E-03	.42101945E-03
25	N2	.83288088E-01	.77030914E-01	26	O	.53167127E-05	.86170880E-05
27	OH	.26856337E-03	.46801152E-03	28	O2	.10068968E-05	.15303169E-05

EXPANSION CONDITIONS KINETIC EXPANSION AREA RATIO 10.000

FLOW PROPERTIES

MACH NUMBER	.30783421E+01
PRESSURE (PSIA)	.88497800E+01
VELOCITY (FT/SEC)	.86320038E+04
DENSITY (LB/FT3)	.68871128E-02
TEMPERATURE (DEG-R)	.34867861E+04
ENTHALPY (BTU/LB)	-.21882884E+04
GAS MOLECULAR WEIGHT	.28159889E+02
HEAT CAPACITY(BTU/LB-DEG)	.41953267E+00
GAMMA	.12884088E+01
CURRENT ROOVOA	.50857001E+02
MOLECULAR WEIGHT(MIX)	.25034846E+02

PERFORMANCE PARAMETERS

VACUUM THRUST COEFFICIENT	.17685906E+01
VACUUM SPECIFIC IMPULSE (SEC)	.28521407E+03

INTEGRATION PARAMETERS

STEP SIZE	.50000000E-02
AXIAL POSITION	.53022062E+01
PERCENT ENTHALPY CHANGE	-.52925368E-01
PERCENT MASS FRACTION CHANGE	.26503264E-00

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.60429063E-05	.56082752E-05	2	ALCL	.17266871E-01	.50868438E-02
3	ALCL2	.16636337E-01	.38781440E-02	4	ALCL3	.72059357E-03	.16172357E-03
5	ALH	.80111215E-17	.76236490E-07	6	ALO	.44586762E-05	.26905906E-05
7	ALOCL	.80847144E-02	.26435705E-02	8	ALOH	.33849310E-03	.19976204E-03
9	ALO2	.18447133E-05	.82646637E-06	10	ALO2H	.94712590E-03	.41019332E-03
11	AL2O	.23731626E-04	.88680179E-05	12	AL2O3(S)	.27731467E+00	.70700350E-01
13	AL2O3(L)	0.	0.	14	CO	.24403206E+00	.24707066E+00
15	CO2	.31701210E-01	.18461253E-01	16	CL	.35282734E-02	.24790034E-02
17	CLO	.68347180E-08	.26371617E-08	18	CL2	.31768460E-06	.11615926E-06
19	H	.29546224E-03	.74812508E-02	20	HCL	.19121606E+00	.13602645E+00
21	HO2	.11870814E-08	.87858097E-09	22	H2	.23706463E-01	.30616890E+00
23	H2O	.84213067E-01	.12127269E+00	24	NO	.54713723E-03	.62107612E-03
25	N2	.83209860E-01	.77861207E-01	26	O	.30063156E-05	.48710770E-05
27	OH	.16074610E-03	.25886601E-03	28	O2	.11365124E-05	.81950034E-06

EXPANSION CONDITIONS KINETIC EXPANSION AREA RATIO 20.000

FLOW PROPERTIES		PERFORMANCE PARAMETERS	
MACH NUMBER	.35418547E+01	VACUUM THRUST COEFFICIENT	.18560302E+01
PRESSURE (PSIA)	.32095934E+01	VACUUM SPECIFIC IMPULSE (SEC)	.29931513E+03
VELOCITY (FT/SEC)	.98386880E+04		
DENSITY (LB/FT3)	.28877690E-02		
TEMPERATURE (DEG-R)	.29731062E+04	INTEGRATION PARAMETERS	
ENTHALPY (BTU/LB)	-.23417067E+04		
GAS MOLECULAR WEIGHT	.26154784E+02	STEP SIZE	.50000000E-02
HEAT CAPACITY(BTU/LB-DEG)	.44186398E+00	AXIAL POSITION	.80264300E+01
GAMMA	.12155164E+01	PERCENT ENTHALPY CHANGE	-.52626560E-01
CURRENT [illegible]	.58767847E+02	PERCENT MASS FRACTION CHANGE	.60927702E-00
MOLECULAR WEIGHT(MIX)	.25030988E+02		

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.30817610E-05	.23626877E-05	2	ALCL	.13421072E-01	.55762003E-02
3	ALCL2	.10890615E-01	.26266665E-02	4	ALCL3	.36076957E-03	.70101187E-04
5	ALH	.10362472E-07	.95867636E-08	6	ALO	.17781652E-05	.10731100E-05
7	ALOCL	.10679252E-01	.33113428E-02	8	ALOH	.29560007E-03	.17648907E-03
9	ALO2	.80174521E-06	.39218396E-06	10	ALO2H	.86786273E-03	.41040004E-03
11	AL2O	.14290316E-06	.71297557E-05	12	AL2O3(S)	.27703167E+00	.70709006E-01
13	AL2O3(L)	0.	0.	14	CO	.26623778E+00	.26454768E+00
15	CO2	.32226082E-01	.18007050E-01	16	CL	.32344159E-02	.23479006E-02
17	CLO	.33764063E-08	.17812023E-08	18	CL2	.44017906E-07	.16102751E-07
19	H	.29715972E-03	.44177174E-02	20	HCL	.19916097E+00	.13701691E+00
21	HO2	.37910316E-10	.25320093E-09	22	H2	.21860211E-01	.30712372E+00
23	H2O	.83811102E-01	.13026157E+00	24	NO	.64713723E-03	.42110014E-03
25	N2	.83290808E-01	.77067323E-01	26	O	.12610419E-05	.20167377E-05
27	OH	.73680085E-04	.11226356E-03	28	O2	.50130224E-06	.40044036E-06

EXPANSION CONDITIONS KINETIC EXPANSION AREA RATIO 30.000

FLOW PROPERTIES

MACH NUMBER	.39460073E+01
PRESSURE (PSIA)	.14007974E+01
VELOCITY (FT/SEC)	.93398681E+04
DENSITY (LB/FT3)	.18889631E-02
TEMPERATURE (DEG-R)	.27951438E+04
ENTHALPY (BTU/LB)	-.26609736E+04
GAS MOLECULAR WEIGHT	.20195200E+02
HEAT CAPACITY(BTU/LB-DEG)	.39939000E+00
GAMMA	.12701194E+01
CURRENT GROUPS	.50421790E+02
MOLECULAR WEIGHT (MIX)	.25030508E+02

PERFORMANCE PARAMETERS

VACUUM THRUST COEFFICIENT	.18008739E+01
VACUUM SPECIFIC IMPULSE (SEC)	.30628430E+03

INTEGRATION PARAMETERS

STEP SIZE	.50000000E-02
AXIAL POSITION	.12900613E+02
PERCENT ENTHALPY CHANGE	-.52629577E-01
PERCENT MASS FRACTION CHANGE	.59717031E-00

CHEMICAL COMPOSITION

NO.	SPECIES	MASS FRACTION	MOLE FRACTION	NO.	SPECIES	MASS FRACTION	MOLE FRACTION
1	AL	.10300537E-05	.18841756E-05	2	ALCL	.13960006E-01	.57707140E-02
3	ALCL2	.85859161E-02	.22154056E-02	4	ALCL3	.23192703E-03	.44082230E-04
5	ALH	.27429900E-08	.25606803E-08	6	ALO	.96633040E-06	.58180790E-06
7	ALOCL	.11290700E-01	.37360480E-02	8	ALOH	.27640151E-03	.16290090E-03
9	ALO2	.56000670E-06	.26144036E-06	10	ALO2H	.96833270E-03	.41871810E-03
11	AL2O	.16792104E-06	.62111190E-05	12	AL2O3(S)	.27703167E+00	.70707904E-01
13	AL2O3(L)	0.	0.	14	CO	.26610597E+00	.26603139E+00
15	CO2	.32037060E-01	.10115537E-01	16	CL	.30971260E-02	.22060460E-02
17	CLO	.61079261E-10	.31100730E-10	18	CL2	.13206310E-07	.08041071E-08
19	H	.23708416E-03	.41362990E-02	20	HCL	.19011502E+00	.13010060E+00
21	HO2	.18779673E-30	.14753902E-00	22	H2	.23604796E-01	.30751163E+00
23	H2O	.83109096E-01	.11079063E+00	24	NO	.60713723E-03	.42111407E-03
25	N2	.83200960E-01	.77460127E-01	26	O	.70040603E-06	.11407063E-05
27	OH	.62621064E-06	.64701091E-06	28	O2	.30849036E-06	.25023766E-06

EQ NOT REACHED

SUMMARY OUTPUT FROM ODK MODULE

A/A*	ISP(ODK)	ETA(KIN)
2.00000	236.42000	.99906
4.00000	260.60700	.99851
6.00000	272.43310	.99833
10.00000	285.21400	.99736
20.00000	299.31500	.99587
30.00000	304.22400	.99495
30.00000	304.22400	

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6. Harry, D. P., Price, C. F., Small, K. R., and Taylor, D. E., "User's Manual For Nozzleless Rocket Motor Internal Ballistics Computer Program," AFRPL TR-73-20, March 1973.

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8. Stull, D. R., and Prophet, H., "JANAF Thermochemical Tables, Second Edition," National Bureau of Standards NSRDS-NBS 37, June 1971.

9. Pieper, J. L., "ICRPG Liquid Propellant Thrust Chamber Performance Evaluation Manual," CPIA No. 178, September 1968.

10. Thiokol Chemical Corp., Elkton Division, Elkton, Maryland "TE-M-364-4 Extended Delta Rocket Motor" Final Report NASA Contract NAS7-678, 1972.

Appendix A - Control Card Set Ups

Control card set ups for two typical cases are shown for both CDC 6000 (SCØPE 3.3) and Univac 1100 (EXEC 8) seires computers and operating systems. In both cases absolute versions of the SPP code and the thermodynamic data files are assumed to be on permanent mass storage data files.

The first case considered is when one or more of the computational modules are executed and the linkage data is written (punched) out for subsequent runs.

The second case considered is when linkage data from the first case is used in executing subsequent modules for the same motor.

The bracket symbol (|) is used to explain or comment on the function of the control cards. Since the first, and most likely the second, control card of each set varies from installation to installation even for the same computer and operating system. The accounting information control card is left off from each set and the job specification control card (normally the second control card in the set and the first shown here) should be checked for consistancy at each installation.

CASE I: CDC 6000 Series Computers

```
JØB, CM10000, CL126000, T700*, IØ1000.
ATTACH, SPP, SPPABS.       | get SPP absolute
ATTACH, TAPE 25, SPPTHERMØ  | equate thermo data to logical unit 25
RFL, 126000.     | request core to execute SPP program
SPP.    | execute the SPP program
7/8/9
         program data
6/7/8/9        end of file
```

CASE I: Univac 1100 Series Computer.

```
@ASG,AX   SPP.   | assign program file
@ASG,AX   SPPTHERMØ.+   | assign thermo data
@USE 25.,   SPPTHERMØ.+   | equate logical unit 25 to thermo data
@ASG,U   LINKDATA.,F   | assign a file for the linkage data
@USE   8., LINKDATA.   | equate logical unit 8 to the linkage data file
```

```
@XQT   SPP.SPP       | execute the absolute element SPP from the SPP file
    program data
@FIN
@@    | remote job entry end of file
```

CASE II: CDC 6000 Series Computers

```
JØB, CM10000,CL126000,T700*,IØ1000.
ATTACH,SPP,SPPABS.
ATTACH,TAPE25,SPPTHERMØ.
CØPYBR,INPUT,TAPE3.    | copies previously generated linkage data to TAPE3.
REWIND(TAPE3)
RFL,126000.
SPP.
7/8/9
    linkage data from Case I
7/8/9
    program data
6/7/8/9
```

CASE II: Univac 1100 Series Computers

```
@ASG,AX        SPP.
@ASG,AX        SPPTHERMØ.+
@USE           25.,SPPTHERMØ.+
@ASG,AX        LINKDATA.**
@USE           3.,LINKDATA.**
@ASG,U         LINKDATA2.,F      | assign and equate further linkage
@USE           8.,LINKDATA2.     | data to unit 8
@XQT           SPP.SPP
    program data
@FIN
@@
```

NOTES:

* CPU time limit depends on modules to be executed.

\+ Only needed if the ØDE and/or ØDK modules are to be executed.

** If this data has been punched, the following control cards can be used:

```
@ASG,T  3.,F4
@DATA,I  3.
  linkage data from Case I
@END
```